

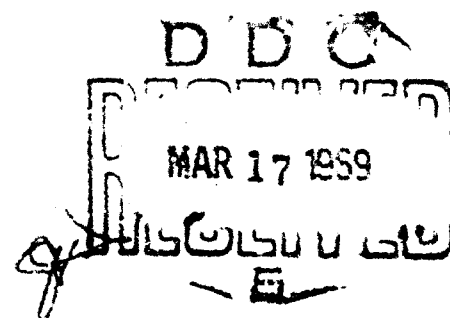
QUALITY AND RELIABILITY ASSURANCE
TECHNICAL REPORT

TR 9

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ZERO DEFECTS

THE QUEST FOR QUALITY



15 AUGUST 1968
OFFICE OF THE ASSISTANT SECRETARY OF DEFENSE
(INSTALLATIONS AND LOGISTICS)
WASHINGTON, D.C. 20301

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INSTALLATIONS AND LOGISTICS

August 15, 1968

Zero Defects -- The Quest for Quality

TR-9

Technical Report Number 9, "Zero Defects - The Quest for Quality," is approved for printing and distribution. The purpose of this publication is to stimulate ideas and encourage programs aimed at improving the quality of manufactured products and of services. The viewpoints expressed by the contributing authors are their own.

George E. Fouch
GEORGE E. FOUCH

Deputy Assistant Secretary of Defense
(Logistics Management Systems and Programs)

PREFACE

Who isn't interested in quality? Who amongst us, does not fret and complain when this or that gadget disappoints our expectations? To some extent all of us are quality minded -- particularly when defects and failures strike at our personal well-being.

Not unlike you and me, the Department of Defense is also quality minded. Understandably so! National security hinges critically on the quality of millions of military items ranging from nuts and bolts to space hardware. It is no wonder, then, that the Department of Defense (DOD) spares no effort in establishing and enforcing high but reasonable standards of quality. Yet some defects slip through the DoD's defensive screen to bedevil consumers and users. These defects have their roots in design, development, engineering, specification, production, testing, quality control, maintenance and, as we all well know, in the "human condition."

In an industrial and governmental context there is good reason for believing that the great preponderance of defects are traceable specifically to dispirited persons who wearily go about their appointed duties in the shops, drafting rooms, offices and executive suites of the industrial and governmental world. But there is nothing new or profound in suggesting that "people" cause defects or hang-ups, call them what you will. What is new -- or relatively so -- is the growing conviction that defects are largely preventable provided industrial and governmental organizations translate fundamental concepts of motivation and quality control into operational practice.

The conviction of "preventability" has generated a lively movement -- with a strong grass roots base -- to counteract defectiveness. The movement flies under many flags but is most commonly called "Zero Defects (ZD)." Its aim is to find ways and means by which people can better relate to their work through improved motivation and communication. Zero Defects -- or "ZD" for short -- is premised on the elementary principle that most people want to do the right thing. But they also want to be heard. They want to communicate effectively with those above, below, and beside them, and they want visible recognition for work well done.

The Department of Defense has encouraged the Zero Defects movement and has established Zero Defects Programs throughout its various activities. This interest was well manifested by the publication in 1965 of Quality and Reliability Assurance Handbook 4155.12-H entitled, "A Guide to Zero Defects." At the time this Handbook was published it was recognized that the surface had been hardly scratched and that there was need for more intensive development of subjects pertaining to ZD. Accordingly, the Department of Defense undertook the development of a follow-on publication. As this project progressed it was soon evident that the proposed publication would have limited utility unless it addressed itself to a broad mix of subjects beyond the motivational. Thus, it was decided that the publication should encompass economic, managerial and technical considerations as well as ideas and techniques pertaining more narrowly to ZD. It was decided that these subjects should be treated by authors representative of the industrial and academic fraternities as well as of the Department of Defense. Accordingly, the Department of Defense in cooperation with the National Security Industrial Association invited qualified authors to prepare papers on selected topics. Each author was given the fullest latitude in developing the topic assigned to him even though it was foreseen that this would result in some duplication of subject matter.

The purpose of this publication is to give clear visibility to ideas and techniques that are useful in establishing programs to prevent defectiveness. ~~This is not a "how-to-do-it" book.~~ Rather it is a compendium of the individual points of view and experiences of persons who have used the weapons of psychology, economics and various management sciences to grapple with quality problems. Specifically it is expected that this publication will be useful in developing and improving ZD programs. Hopefully, also, it will be useful as a reference text for training and discussions.

The editor is hard pressed to acknowledge fully his indebtedness to all those who have assisted in the preparation of this publication. It is a pleasure to thank the National Security Industrial Association for its cooperation and the contributing authors for their tolerance and patience. For technical advice, acknowledgement is made to Mr. Richard P. Hussey, Department of the Air Force, to Mr. Milton Cohen, International Telephone and Telegraph Company and President of the American Society for Zero Defects, and to Mr. Irving B. Altman, Office of the Assistant Secretary of Defense (Installations & Logistics). It is a pleasure also to acknowledge the cheerful secretarial assistance of Mrs. Genevieve W. Tidd and Mrs. Dorothea E. Sullivan. This

publication would not have progressed beyond the draft stage without the continuing interest of Mr. George E. Fouch, Deputy Assistant Secretary of Defense (Logistics Management Systems and Programs) and the services of Mr. Lloyd H. Blevins, National Institutes of Health (formerly of the Food and Drug Administration) who served as assistant to the editor. For perceptive editorial counsel and for substantial editing assistance the editor is most grateful to TRW Systems and specifically to Mr. Herbert H. Rosen, Director, Technology Utilization and Mrs. Mary C. Buie, Senior Production Editor.

It need hardly be said that any publication that deals with Zero Defects puts its editor in the unenviable position of attempting to practice faithfully what he preaches. No little effort has been expended to exorcise impish gremlins from between the covers of this text. But if they have eluded detection and have perpetrated their mischief on this page or that, please be assured that the editor is receptive to Error Cause Removals (ECR's) as orthodox ZD doctrine prescribes.

John J. Riordan, Editor
Director for Quality and
Reliability Assurance

OUTLINE

MANAGEMENT AND HUMAN PERFORMANCE

Peter B. Vaill
Graduate School of Business Administration
University of California, Los Angeles

An examination of the key-variable factors influencing man's performance on the job and the utilization of those factors in a program of planned performance improvement, illustrated by case studies.

ECONOMICS OF DEFECTIVENESS

William R. Pabst, Jr.
Naval Ordnance Systems Command, Washington, D. C.

An assessment of the cost of the programs for eliminating or reducing defectiveness—the "gold in the mine"—as compared to the cost of the potential gain.

QUALITY THROUGH FUNCTIONAL PLANNING

John W. Young
Vice President
Quality and Logistics
North American Aviation, Inc.

The importance of "upper-level" managements' handling of quality assurance policies and practices to satisfy its customers needs while maintaining its competitive posture.

"ZERO DEFECTS" TYPE PROGRAMS—BASIC CONCEPTS

Captain E. R. Pettebone, USN
Commanding Officer, Naval Ammunition Depot
Greene, Indiana

A review of what a Zero Defects program is—and is not—and the necessary "building blocks" to organize and implement a successful program.

TECHNICAL CAUSES OF DEFECTIVENESS

Frank McGinnis
Director of Reliability, Maintainability, and Quality
Sperry Gyroscope Company

An analysis of technical conditions leading to defectiveness in terms of specifications, design, production, and use.

OUTLINE (Continued)

PROBING AND ELIMINATING CAUSES OF DEFECTS

Alfred S. Wall
Manager, Defense Quality Assurance
Defense Electronic Products
Radio Corporation of America
Camden, New Jersey

A study of defect causes, with suggestions for the elimination, control, or prevention of the problem through the application of highly specialized skills and effective managerial steps.

ASSESSMENT OF PROBLEMS AND OPPORTUNITIES

K. F. Wasmuth
Company Director of Quality
Martin Company

An examination of practical and plausible opportunities for application of a Zero Defects program in the areas of manufacturing and software, i. e., paperwork and related systems.

ASSESSING PROGRAM EFFECTIVENESS

Anthony R. Tocco
Director Value Assurance
TRW Systems Group, Redondo Beach, California

An appraisal of the basic principles common to all good Zero Defects programs, with assessment checkpoints for a specific company program. Types of measurement techniques are illustrated and comparisons made between theory and practice.

QUALITY EDUCATION PROGRAM

K. E. Joy
United States Army Missile Command
Huntsville, Alabama

The need of a good quality education program within a company is treated in the paper, with an evaluation and implementation of such a program. Also discussed are advanced training techniques.

DETAILED GUIDE FOR PROGRAM PLANNING

J. Y. McClure
General Dynamics Corporation

A step-by-step explanation of implementation of a Zero Defects program, through organization and administration, goal-setting and external/internal interfaces, to awards and promotion. A Motivation Program Planning Checklist is given at the end of paper.

OUTLINE (Continued)

SUSTAINING THE ZD PROGRAM

Merle V. Zimmer
Vertol Division, The Boeing Company

A discussion of techniques to create and sustain interest so that the Zero Defects program is a dynamic and successful one.

INNOVATION AND RESEARCH

O. A. Cocca, AFLC
Wright Patterson Air Force Base

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MANAGEMENT AND HUMAN PERFORMANCE

Peter B. Vaill
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Man's performance on the job is influenced by many factors—factors that are interrelated and can combine themselves in different ways. To understand these factors, they must be viewed as a system, in that any one factor cannot be isolated from or manipulated independently of the others. By using the case study technique, this paper discusses the causes—the factors—of human performance at work to the end of raising the level of performance if it is desirable and realistic to attempt to do so.

The Meaning of Performance

The first measure of performance that usually comes to mind is "productivity," defined typically as volume of output per unit time. Another dimension to performance, at least as important but more difficult to measure, is quality. Modern measures of productivity often try to take account of both. But, of late, performance has come to be viewed even more broadly.

At its base, "human performance" is a man's behavior during his eight hours on the job—his total behavior. Everything he does in that time affects the organization in one way or another. However, the dollar value attached to the consequences of his behavior on the job is difficult to measure.* For instance, a man may decide to talk to his supervisor. The cost to the organization is the man's time away from his work plus

* There is a continuous search for ways of determining such dollar costs, however. One of the more intriguing efforts will be found in L. E. Davis and R. R. Cantor, "Job Design," The Journal of Industrial Engineering, January 1955, p. 1 ff.

the supervisor's time. The organization profits if the conversation produces an idea or a mood in the man that improves his performance when he returns to the job. But no organization would attempt to determine if the conversation was a justifiable "investment."

Events off the job often affect performance. If the man wins in the luncheon card game, he may return to work ready to give increased effort. The losers, on the other hand, may slack off in the afternoon. What happens at lunch tends to influence men through the afternoon, one way or another.

Controls on Behavior

As companies become aware of the impact of behavior on profit, they generate rules and regulations designed to encourage some kinds of behavior and prohibit others. Most companies reward employee suggestions, for instance. On the prohibitive side, regulations discouraging or prohibiting "horseplay" are nearly universal. Rules and regulations reflect a company's increased interest in controlling behavior. They also reflect the decline in importance of setting up the job so that the man will produce at the desired level. Job design used to be thought of as the key to performance; once the job was perfected according to scientific principles, the man had no excuse for performing poorly. Instead, job design is being viewed increasingly as one of several factors which jointly determine performance.

The administration of human work systems, therefore, must ask itself new questions:

How can we encourage the employee to desire advancement?

How can we get him to cooperate with the others around him whose jobs are linked to his in the workflow?

How can he be encouraged to make suggestions?

How can we get a man to follow the leaders around him constructively rather than blindly so that he will feel free to speak up if he has something to offer?

How can he be taught and encouraged to take care of all the costly equipment he is using so that its productive life will be maximized?

How can the man become committed to company goals and come to take personal pride in the products he has a hand in producing?

How can he be educated in the economic realities of the business so he will understand that the wage or salary he earns is not an arbitrary or capricious figure?

All of these considerations go into "work performance" as this employs the term, although few of them can be measured directly and incorporated into a performance index. Many are not about a man's skill or his manual operations so much as they are about his knowledge, attitudes, and feelings about the job he is doing. No longer can a businessman say, "As long as my boys put out 100 percent on the machines, I don't care what they think about me or the company." Advancing technology and dynamic markets demand flexible adaptation by everyone within the organization, and what the employee is thinking and feeling affects performance—and profits—directly.

The Determinants of Performance

Work performance therefore means the totality of a person's behavior at work. If a company wants to improve the quality of employee's work, it must treat quality as part of a system of behaviors. In raising the level of quality, the company must deal with a whole system of factors.*

* The idea that the causes of human behavior are multiple, not single, and further that these multiple causes constitute a system is a distinction social scientists have insisted upon from the beginning. A useful statement of the point of view as it relates to industrial management may be found in William Foote Whyte, Men at Work (Homewood, Illinois: Irwin-Dorsey, 1961) especially Chapter 2. F.J. Roethlisberger's Management and Morale (Harvard University Press, 1941) contains a less formal but no less intriguing discussion of the same subject in Chapter 4, "The Social Structure of Industry."

The number of factors causing a given level of performance is virtually infinite. However, five of these have received the bulk of attention by theorists and researchers, and are considered the key variables in any program of planned performance improvement:*

- Personality
- Group membership
- Task structure
- Supervisory behavior
- Organization climate

The approach of this chapter is to conceive a man's performance as being the product of a combination of his own personal characteristics, the influences on him of the group in which he works, the nature of the work he is doing, the type of supervision he receives, and the climate of the organization in which he works.**

* Books which the writer has drawn upon for his ideas about each of these five factors include:

Personality:

A. Combs and D. Snygg, Individual Behavior, 2nd ed. (New York: Harper & Bros., 1957).

Group membership:

G. C. Homans, The Human Group (New York: Harcourt, Brace & Co., 1950).

Task structure:

Charles Walker, Modern Technology and Civilization (New York: McGraw-Hill Book Co., 1961).

Supervisory behavior:

Douglas McGregor, The Human Side of Enterprise (New York: McGraw-Hill Book Co., 1960).

Organization climate:

W. Bennis, K. Benne, and R. Chin, The Planning of Change (New York: Holt, Rinehart, and Winston, Inc., 1961).

** One of the best statements of how factors may combine themselves in their effects on behavior may be found in F. J. Roethlisberger, Training for Human Relations (Boston: Harvard Business School, Division of Research, 1954) Chapter 8.

Clearly, these five factors are related to each other. The supervisor's expectations of a man probably will influence the man's "expectations" of himself. Other members of the work group will have much in common with him (e.g., education, past experience, etc.). Hence, the group's expectations will probably parallel the man's expectations—getting ahead, not angering management unduly, performing the job up to some standard and the like.

Matches and Mismatches

The emphasis on "expectations" is not out of proportion to the real work situation. Each work group contains a representative cross section. Some, however, are populated with some or all of the extremes illustrated below.

If a man's own needs are totally out of line with the group, the supervisor, the task, and the organization, and he goes ahead and behaves in a way to satisfy only his personal needs, we call him "selfish."

A person who lets the group's expectations of him govern his behavior completely we call a "conformist."

A person who is dedicated only to the performance of the task may be known variously as a "grind" or a "perfectionist."

A person whose only concern is pleasing his supervisor is usually known as an "apple-polisher" or a "fair-haired boy."

A person whose behavior is governed not by the immediate expectations of those around him or even of his own needs and feelings but is motivated rather by the broader, more global expectations of the organization to which he belongs, we usually call an "idealist" or sometimes a "fanatic." This fifth type is encountered more often in political and religious organizations than in business.

For the most part, it is difficult to work with these "negative" people. Their very narrowness and single-mindedness make it difficult for them to act in ways that are appropriate to the needs of a given situation, which is to say, in ways that satisfy those around them. They are people who have solved the problem of balancing the various demands

of specific situations. Unlike most men their behavior seems rigid and at times almost compulsive.*

Most men do not adopt such extreme solutions to the complexities of life as these five types. Instead they balance, test, adjust, react to consequences, and make modifications in their actions continuously. These men constitute the vast majority and, hence, are the people with whom managements must work to raise levels of performance in the organization.

Most men seek continually to satisfy their own needs while meeting the demands of the groups to which they belong—their supervisors the jobs they do, and the organization that employs them. Because men, groups, supervisors, jobs, and organizations differ, men often find it easier to create behaviors that meet the needs of pairs and triplets of the five "key variable" factors than they do of all five simultaneously. When a man finds it easy to meet his own needs and also satisfy the expectations of his group, the process is called a "match." A "mismatch" occurs when he is unable to get interested in his job as it is set up. From his point of view he has tried but he just cannot feel wholly comfortable on the job for a number of reasons—it lacks challenge, it demands talents he does not have, it isolates him from others, etc. A conflict—or mismatch—has arisen between what he wants to do and what the job demands of him. Matches and mismatches can occur between any pair of these five factors, and when they do, management's task will be fundamentally different in a performance improvement program.

The combinations of matches and mismatches are varied and large in number. Literally, every situation is somewhat different. The case studies that follow are illustrative of four common types of matches/mismatches. Each suggests how management might implement a performance improvement program if the given set of conditions actually exist in the organization. More important is disclosure of the process

* Most books on psychology deal with this type of person. Few such discussions are as useful for the layman as Elton Mayo's Notes on the Psychology of Pierre Janet (Boston: Harvard University Press, 1948).

by which management may adjust its planning to real, here-and-now conditions. However, there is no one way to implement a performance improvement program. The method is contingent on the system from which improved performance is desired. *

Case 1: The Nineteenth Century Ideal

Much of the early literature on human behavior in organizations assumed that the bonds within an organization were between men and their work, and between men and their formal supervisors. It was further assumed that the formal supervisors exercised complete control over the climate of the organization and over the specific content of the tasks men performed. ** It has since been shown conclusively that all organizations are not like this and that organizations should not necessarily attempt to become like this, although some organizations today approximate this condition. Many sales forces, for instance, do not exhibit much cohesion among the salesmen. Salesmen meet only periodically to receive new instructions and information from the sales manager. The rest of the time, communication tends to be between individual salesmen and the manager.

Matches occur between individual men and the task, supervisor and organization. Furthermore, task, supervisor, and organization match each other in their demands: they are relatively consistent. For example, a job in sales requires great persuasive talents. The sales manager may believe strongly in the "hard sell" technique and that the best way to motivate salesmen is to have them compete with each other. The organization may pride itself on being an aggressive, fast-moving operation that is never bested on price or volume. Each salesman individually may share these values but is so busy living up to them and competing with the other salesmen, that no strong sales group ever develops.

*The process by which a manager learns how to diagnose conditions in his organization is assumed in this paper to be of relatively greater importance than is possession of a "general theory of management."

**The popularizations and interpretations of the writings of Frederick Lewis Taylor typically treat Case 1 as the natural and desirable state.

The first step in attempting a performance improvement program for this case is deciding whether to preserve the prevailing conditions or, while improving performance, to change them. The absence of a strong group at the level where improvement is desired is of primary importance.* If management decides no strong group is desirable, then the program must be administered so that the men involved do not form a group to resist the new pressures for improved performance.

Most strong groups rise in industry because management does something which a collection of men feel is arbitrary and unwarranted. They are literally thrown together into a group by their discovery that they all feel the same way.** If management wants to preserve the condition of low-group cohesiveness, it must ignore, but not actively avoid, dealing with the men as a group. The difference is between failing to encourage group discussion of the program and deliberately prohibiting group discussion of the program. The latter course will almost certainly promote the formation of a more cohesive group.

Management has comparatively little control over the extent to which the men themselves appear to desire more contact with each other. If there are no signs of this desire—riding to work in car pools, submitting group-generated suggestions, spontaneously helping one another—management could employ its existing ways of working with the men to communicate the goals and methods of the improvement program: greater incentives might be offered, procedures might be streamlined, the importance of the program might be underlined repeatedly in various ways.

* The policy decision is itself a difficult one. A useful and up-to-date discussion of the relation between group cohesion and group productivity may be found in Clovis Shepherd's Small Groups (San Francisco: Chandler Publishing Co., 1964), pp. 85-96.

** Roethlisberger and Dickson noted in Management and the Worker: "There is no doubt that the most pronounced overall characteristic of the interhuman activities described was its peculiarly protective or resistive quality." (p. 525) G. C. Homans, op. cit., pp. 86-94, makes a more general analysis of the impact of the environment on the group and of the group's need to survive in its environment.

If management wants to preserve existing conditions and the men involved are satisfied with them* nothing differing from normal need be done in implementing the improvement program.

Implementation is different, naturally, if management and/or the men involved desire to bring about a stronger group. In the literature there are numerous examples of remarkable improvements in performance resulting from the release of group energies where formerly they did not exist or had been blocked.**

The first problem is to remove the conditions which are keeping the men apart. Their cause may be physical isolation from one another, lack of opportunity to discuss common problems, outright suspicion of one another owing to the way individuals are rewarded in the organization, or marked differences in orientation to the work such as may exist between scientists in diversified research and development organizations. Any or all of these causes can prevent group formation. Their continued existence will make management attempts to get people to cooperate more fully appear "phony" and unrealistic.

The second problem is to define the goals of the improvement program in such a way that the interrelation of people's efforts is highlighted. Of course, if their tasks are not interrelated, management should not force it. Better, management might find ways to interrelate

* It should be said that it is more likely that the men will wish for stronger group ties than they will wish to stay relatively isolated from one another.

** Some valuable examples of the group formation process and its attendant positive effects on performance may be found in the following books:

Robert Guest, Organizational Change: The Effect of Successful Leadership (Homewood, Illinois: Irwin-Dorsey 1962).

Lawrence, Paul, and John Seiler, Organizational Behavior and Administration (Irwin-Dorsey, 1965, rev. ed., the "American Radiatronics" case), pp. 345-376.

E. L. Trist, et al., Organizational Choice (London: Tavistock Publications, 1963).

C. R. Walker, Toward the Automatic Factory (New Haven: Yale University Press, 1957).

the tasks. More often, interrelation is real but obscured by ignorance or rivalry. The goal is to create the conditions where those involved can come to perceive the interrelation and hence improve the coordination of their efforts. Men whose efforts are interrelated but who cannot see it typically become involved in arguments over who is at fault when the joint product of their work is substandard. As long as the game of finger pointing continues, realization of the interdependence will not occur.*

Management must expect that implementing the improvement program under new work conditions will be fitful. There will be sporadic slipping back into the old mode. Doubts about the wisdom of "all this group jazz" will spread among the men. Perhaps performance levels will drop at first.** Coaching must be continuous even after everyone is thought to be clear on the goals of the program. Information on the fruits of their efforts to cooperate must be liberally disseminated. Where the fruits are positive, it is important that participants understand that these consequences flow directly from the increased cooperation. Where they are negative, it can be an occasion for critiquing the working relationships and identifying what is blocking cooperation, but not for the purpose of fixing "blame."

Case 2: The Hawthorne Struggle

In this case, a strong and influential group already exists at the level where improved performance is desired, but the beliefs and practices of the group (or groups) appear to be unalterably opposed to management and to any programs it might try to introduce. It is called the

* Social scientists have consistently stressed the futility of scapegoating and arguing about blame in the process of trying to understand and improve human working relationships. The point is a simple one and is easily grasped. Its practice proves to be more difficult.

** The tortuous process of group development will be found fully described as it appears in industry in Elliot Jacques' The Changing Culture of the Factory (London: Tavistock Publications, 1951). Valuable comments on group development may also be found in Bennis, Benne, and Chin. op. cit., pp. 250-348.

"Hawthorne Struggle" because it was first described in a study conducted by Elton Mayo and his colleagues at Western Electric's Hawthorne Works.*

The employees' needs in this case match each other and, hence, they band together to defend themselves against the arbitrary actions of supervision and the impersonal organization climate. The organization, task, and supervisor, meanwhile, are themselves matched via what the Hawthorne researchers came to call a "logic of efficiency."** The centralized, authoritarian climate of the organization reveals this logic; the design of the task reveals the same logic. The supervisor, in his daily concerns and actions supports the logic as well. Everything—and everyone—above the work level is geared for efficiency.

Whereas, in Case 1 the mismatch of expectations and needs is among men at the level where improvement is desired, in this case the mismatch occurs between this level and levels above it in the organization. In other words, management has to cross a gulf of differences in beliefs and values to make known its interest in improved performance. More simply, "the worker is against the manager." Research literature tends to overgeneralize the Hawthorne Struggle. Claims were made that it represented a universal fact of organizational life. While this is not true, it is true that it occurs sufficiently often to make its discussion useful.

What special challenges does this case present a management which is interested in improving performance? Unlike Case 1, management very likely would have no desire to preserve the gulf

* F. J. Roethlisberger, and W. J. Dickson, Management and the Worker (Boston: Harvard University Press, 1939), Part IV. See also the more recent study, Donald Roy, "Quota Restriction and Goldbricking in a Machine Shop," American Journal of Sociology, LVII:5 (1952), pp. 427-442.

** Roethlisberger and Dickson, op. cit., p. 537, 563-564.

between the formal organization and the work group (or groups). But management's desire for no gulf to exist can easily blind it to the fact that it does. *

The mismatch that characterizes this case can be identified however, by a number of fairly standard indices. The first and most easily detectable index is the practice of "restriction of output" or, as it is sometimes called, "controlled production" by the group or groups on the "other side" of the gulf. ** The research literature demonstrates that such pegged levels of performance by work groups operate to protect itself from management and the larger organization. The term "norms" is used to refer to any codes held by a group which govern the behavior of its members. *** Management, therefore, must attempt to determine the extent to which group norms are operating against the interests of the organization. "Production norms" are often accompanied by other kinds of norms:

"Stay away from the job as long as possible without getting caught. "

"Never do any more for the boss or talk any more to him than you absolutely have to. "

"Never act in a way that requires another group member to accelerate his pace. "

If these norms are practiced, then clearly there exists a serious mismatch between the group's values and behavior, and that of supervision and others in the organization. †

* It is probably the weight of responsibility which clouds the executive's vision on this matter. Developing a realistic view of the organization is one of management's most difficult tasks.

** Roethlisberger and Dickson, op. cit., Part IV. Roy, op. cit. Many useful examples may also be found in W. F. Whyte, Men at Work.

*** Homans, op. cit., pp. 121-127.

† It should be stressed that norms are inferences about the group. The quotations in the text represent what an observer might write. No members of the group would have the norms written down.

Another source of evidence that the Hawthorne Struggle is going on is the first line supervision above the level at which improvement is desired. Consistently encountered resistance, hostility, and extreme difficulty in gaining cooperation is evidence of this case. Conversely, if supervision feels it can work smoothly with the target group, then management more likely faces the conditions of Cases 3 or 4, discussed below.

Clearly, in this case a performance improvement program cannot be installed smoothly without concomitant change in hierarchical relationships. Many companies have found that considerable supervisory training is mandatory before embarking on a performance improvement program. The training enables communication to be re-established with those from whom improvement is desired. Any program that overlooks the gulf (and assumes that by cracking the whip or otherwise manipulating people, improvement can be achieved) will most likely fail in whole or in part.

One way management can communicate its new intentions symbolically is to restructure the tasks to make it possible, for instance, for the groups to use their energy in the work. The research literature confirms that where a group already exists, redesign of jobs to make them congruent with the group's structure can result in remarkable improvement in performance.* For example, a group that has an informal production norm could be given legitimate control over its pace and made responsible for meeting daily or weekly (rather than hourly) targets. Rearrangement of machines or workplaces to make conversation and eye contact easier in the group often improves motivation to work and reduces conflict between the group and supervision. Many companies have had considerable success with payment programs which stressed the group rather than the individual.

* See for instance: Alex Bavelas and G. Strauss, "Group Dynamics and Intergroup Relations," in Bennis, Benne, and Chin, *op cit.*, pp. 587-591. See also Nancy Morse, and Everett Reimer, "The Experimental Change of a Major Organizational Variable," *Journal of Abnormal and Social Psychology*, Vol. 52, No. 1 (January, 1956), pp. 120-129. See also A.K. Rice, *Productivity and Social Organization: The Ahmedabad Experiment* (London: Tavistock Publications, 1958).

These are not big changes or, typically, are they especially costly or time-consuming to effect. They have dual consequences, both for bridging the gulf between the group and supervision: (1) they reduce the mismatch between the demands of the task and the values and codes of the group, and (2) they symbolize management's desire for a smoother working relationship.*

Case 3: The Vacant Middle

It is not uncommon in today's large organizations for middle management to be more sympathetic with the causes of employees down the line than with their managers. In other words, middle management psychologically "joins" those nearer the bottom of the chain of command. (The growth of the white collar union is partial evidence of this trend.) The mismatch in values and practices is, as a result, pushed higher up the organization ladder. Many companies find that the branch plant manager, even though a corporate vice president, is much closer to the beliefs and values of his immediate staff and subordinates than to those held by the headquarters group.

The phenomenon of the "Vacant Middle" can also arise when men are promoted into the ranks of middle management without realizing what they are getting into. They find the more rationalized and efficiency-minded atmosphere of the higher levels not to their liking and so revert to the kinds of feelings and attitudes they had when they worked at the lower levels.

* It is appropriate here to note that a major way that the values and expectations of the larger organization are communicated to employees of it is through symbols. Placing a suggestion box next to a time clock symbolizes something about the organization. The kind and quality of furnishings of offices and the plant says something about the organization. The type of people the organization hires symbolizes something important about its values to the people already on the payroll. W. F. Whyte's Man at Work is a valuable catalog, among other things, of the kinds of objects and processes in the organization which acquire important symbolic meanings for employees.

A different kind of gulf exists in this case than in Case 2, one which top management, nevertheless, will want to bridge or eliminate as it installs a performance improvement program. The initial temptation will be to recover the loyalty and commitment of its middle-level people by increasing the pressure on them to do what they are told. Greater rewards for compliance and more severe punishment for non-compliance with top management directives would follow. However, such a strategy will probably fail to recover the middle-level people, and certainly the performance improvement program's aims will be defeated. Middle managers move downward in the hierarchy in a psychological sense because the pressure and tension from above are too much for them. They will not be converted by increasing the pressure.

To understand the dimensions of management's task under this case some potential causes of present performance need to be examined.* If middle managers abandon their roles, in a psychological sense, it might mean that they do not find their roles satisfy their need for a sense of self worth and their need to feel that they are achieving something important. Upper management must ask itself why middle managers do not feel these needs are being satisfied. One answer may be that middle management does not feel it is being given any hand in the conduct of the affairs of the organization. Some will say they are being loaded down with heavy responsibilities but are not given sufficient authority to discharge them. The idea that authority and responsibility must accompany one another is virtually a cliché, yet there are countless cases where the maxim is violated.

One approach to performance improvement might be to turn over to middle management the authority and responsibility for the design, administration, and evaluation of the program. The program, in other words, could become a watershed in relationships between top and middle management, and an occasion on which top management begins to develop and encourage the sense of achievement and feeling of self worth in the middle managers.

* The discussion in this section draws heavily on Rensis Likert, *New Patterns of Management* (New York: McGraw-Hill Book Co., 1961), and on McGregor, *The Human Side of Enterprise*.

Top management could regard the psychological closeness of middle managers to those below as a resource rather than a liability. If middle managers can exert sufficient control over the program themselves, their closeness to those below will not be threatened. Only if they are placed in the position of having to comply with a detailed program that has been completely designed at the top will they feel they have to choose between those above them and those below. If they are forced to choose, they will probably choose the values and codes of those below them...and the program will fail.

By delegating authority to middle managers for the design and administration of a performance improvement program, top management must abandon the idea of one, single company-wide program that is identical in all its aspects throughout the organization. The goals of performance improvement are established at the top and hence will cut across different units. But the specific features of the program—the detailed techniques by which it is communicated, the incentives that are used, the measures of change that are applied—may well differ from department to department. The performance improvement effort will be an expression of the ideas of the individual manager-in-charge and his innovations must be supported.

In this case, the structure of tasks conforms to organization climate and top management's values. Not only the demands of lower echelon tasks but also those of middle management are mismatches with the needs of the people. This condition arises because staff groups, such as industrial engineering and personnel, are closer to the values of top management than to middle-level and lower-level line people.

Case 3 could arise, in fact, not because of direct actions of top management but rather from the over-zealous efforts of its staff to control completely, thereby deepening the gulf. A performance improvement program that aims to re-establish the sense of self worth and achievement of middle-level people can be defeated by this same over-zealous staff behavior. A personnel man, for example, could rush in to measure the results of a middle manager's program before it had really gotten underway. An industrial engineer could announce that some middle manager's ideas "will never work."

Such interference—and it happens all the time—can defeat the most carefully conducted improvement program that uses delegation of authority to the middle levels. The authority, in other words, must include the power to deal with staff as well as to direct the work of those below the middle manager. If the middle manager is uncertain of his authority to use and not to use staff, he will still feel like a chip tossed on the organizational waters and will not be able to take seriously the delegation of authority to him for performance improvement. Many middle managers have often said, "They tell me I'm running my own show, but they've got staff men all over the place watching me."

Case 4: The Tight Little Island

Sometimes, not only is there a match between the desires of the work group and middle managers, but the demands of the work also fit smoothly into their respective needs. Such a situation arises typically when a strong formal leader (a general foreman, a project manager, a geographically removed plant manager) is granted or wins complete control over his domain and, subsequently, is able to shape it profoundly in the direction he wants. Esoteric research and development projects in the aerospace industry often have this character. One finds the same phenomenon in such service organizations as maintenance departments. The domain has a family-like atmosphere and will have evolved highly effective techniques for reducing the influence of, or shutting out completely, the larger organization.

As long as the "tight little island" performs the work it is assigned in a competent fashion, top management is generally reluctant to attempt to break it up. But the advent of performance improvement will raise the question of how this self-contained domain can be induced to adopt the principles and practices of the program. Two further conditions can complicate the problem for management: if there is good evidence that the self-contained system is badly in need of performance improvement, and/or if management has several such domains in the organization.

Neither of the two strategies suggested under Case 3 are appropriate in this case. The leaders of the self-contained system have already taken or been delegated sufficient authority. The tasks performed by people in the domain already have been reshaped to their needs and tastes. What is management's point of entry to be, assuming that performance improvement within the self-contained domain is clearly needed?

In this case, more clearly than in the previous three, a performance improvement program cannot be imposed.* The domain has enough power to undercut the effort or modify it so that the organization goals the program contained originally are no longer pursued. It is true, of course, that top management could force compliance—by such devices as removing the leaders, cutting its budget drastically, or (in a diversified company) threatening to sell the unit. But such pressure and power-based solutions would destroy the very real and potentially valuable strength of the well-organized domain. Management's problem is how to gain an entry and influence without wrecking it.

When working with a relatively self-contained domain with strong leadership at its top, management must first communicate the logic behind the performance improvement program. The leaders of the domain must become convinced that the program is in the interests of their domain as well as of the larger organization. The program may hold out potential cost savings, for instance, which could be plowed back into improved equipment for his own domain. The successful installation of the program may bring prestige in the company and, often, in the industry.

*Some intriguing alternatives to "imposition" as a managerial style may be found in Robert Tannenbaum and Warren H. Schmidt, "How to Choose a Leadership Pattern," in Robert Tannenbaum, Irving Weschler, and Fred Massarik, Leadership and Organization (New York: McGraw-Hill Book Co. 1961), pp. 67-79 and especially p. 69.

Top management's approach to a self-contained unit has to be more consultative than power-based. Top management's goal must be to help, not force, the unit to conduct its internal affairs more efficiently. These two conditions seem essential: a program that has a logic behind it grounded in reality, and an honest desire to help the unit function better. Failing either condition, it can be expected that the attempt to install a performance improvement program in a self-contained unit will cause it to feel under attack and hence to marshal all the defenses it has developed to shield it from the larger organization.

Case 5: A Hypothetical Ideal

Although myriad cases of mismatches exist between two or more of the five factors of personal needs, group demands, task demands, supervisory expectations, and organization climate, there seems to be no obvious reason why these mismatches occur. It is not unrealistic, in other words, for management to attempt always to work through mismatches with the longer-term objective being a kind of organization that automatically corrects for mismatches whenever and wherever they occur.*

Looking at such an organization from the point of view of an individual employee, we would describe his role as follows: he was able, in the ordinary course of daily activity to satisfy his own needs while performing the task up to standard, while satisfying the expectations held of him by the group in which he worked and the expectations of his supervisor, while being able to subscribe honestly to the larger organization's goals and still feel his own efforts were contributing to the achievement of these goals. To keep the discussion from becoming too utopian, we will say that an organization where most people are able to balance all these demands most of the time satisfies the criterion of true

* This type of self-regulating process is often discussed as a process of maintaining "equilibrium." Equilibrium has been criticized by some because it seems to imply an end point where the organization becomes relatively static and monolithic. Clearly the Case 5 organization is anything but static and monolithic.

organizational health. Additionally, to meet this criterion, an organization should contain mechanisms for the resolution of gross imbalances when they occur.

Performance improvement programs are a class of such mechanisms. Even an organization where this balancing process was being well executed could be expected to be able to further improve its performance. The philosophy and practice of performance improvement discussed throughout this book is such a value system which, even in the most healthy organization, can serve as a source of new goals and new standards against which people may evaluate their actions. The difference in performance improvements between the fifth case and the previous four is that in the latter, the programs are superimposed on existing patterns. Such programs are "new and different," a shift of gears, as it were. In this fifth case, on the other hand, the idea of continuous performance improvement is an integral part of the organization's conduct—an element that seems as natural and unremarkable to everyone as the fact that everyone who works for the company gets paid.

What we are suggesting is that ultimately "performance improvement" means the very process by which an organization moves toward the condition that is Case 5. All four of the sample cases that precede the fifth, and the many other mismatches that exist, are suboptimal in one way or another. People's energies are being drained off in attempts to defend themselves where they are under attack and to assert themselves where they feel they are being ignored. In Case 5, the individual man, whether at the top or the bottom level, works with his hands and his mind without needing to glance over his shoulder at the boss, or to watch his friends out of the corner of his eye, or to struggle with his conscience about whether he is committed to values of the larger organization and to its culture.

ECONOMICS OF DEFECTIVENESS

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Everyone talks about defectiveness. But no one really knows the part defectiveness plays in our national life or how it can be eliminated.

Defectiveness is the inverse of effectiveness. Effectiveness connotes the total value of a system. Defectiveness has a negative or hidden aspect about it. It has been characterized as the economic underworld or the underworld of quality. Defectiveness, like unemployment, underutilization, undercapacity, and other similar negative terms, represents the inverse of what we can see or measure. But the measurement of most of these hidden qualities is difficult at best, and the measurement of defectiveness in meaningful economic terms is very nearly impossible.

We know defectiveness exists. Twenty-five per cent of the automobiles tested failed the District of Columbia inspection. Automobile manufacturers consistently recall their cars for defective brakes. Electrical safety defects in household products cause untold fires. The problems in television, radio, automobile, and appliance servicing are legion.

With all this evidence in hand, it is reasonable to suggest that industry know more accurately what defectiveness costs, if not for its nuisance value to the customer, then at least to ascertain if profits can be improved by eliminating it.

A full discussion of defectiveness involves social, political, and economic considerations; however, our attention here will be largely on the economic and pecuniary aspects of defectiveness in terms of the plant or individual, the industry, and the nation. Some ways of observing defectiveness will be discussed, and the economics possible through the elimination of defectiveness reviewed, as given by Juran, Feigenbaum, and others. Profit-sharing, incentive programs, and value engineering which acts as a restraint on defectiveness will be included, as well as the nature of defectiveness as identified in the technical and statistical literature of quality control.

Further, we shall take the analysis of the decision-making firm and extrapolate it in terms of its impact on the economy as a whole. Avoiding a utopian view in going from the concepts of a perfect product to that of a perfect society will be difficult. So will enlarging the concept of defectiveness from individual products to whole industries to the whole economy, especially in terms of unemployment, underutilized resources, and wasted natural resources (smog, polluted streams, etc.).

Despite these difficulties, aim to take the measure of defectiveness and assess the tremendous value of industry and government in combating it.

Observing Defectiveness

Defectiveness may be difficult to define and measure; but its existence is detected. For the purpose of this discussion, consider five signs as the source of quantitative appraisal.

- Steps taken to eliminate defects, and the measured results
- Tally of the defective products on the market
- Condition of products reaching the ultimate consumer
- Percentage of defective incoming supplies
- Hazardous and unsatisfactory products as disclosed by private and governmental test activities

The steps taken to eliminate defectiveness have become symbolized under a nation-wide program known as Zero Defects, or ZD. Numerous companies in the United States and abroad have found that the attention and visibility given to the problem of defectiveness by the ZD program have produced significant and surprising results. One company reduced its scrap by 76 percent and its rework by 94 percent in its first ZD year. Others report reductions in scrap and rework rates ranging from 35 to 75 percent.^{1*} Not only is the manufactured or assembled product improved, but paperwork errors, delays in handling, and administrative and clerical errors also are reduced.

* See reference list at end of paper.

Not only have most of the companies participating in the Zero Defects program found a sizable quantity of defects in their operations, but, more important, most companies have discovered that a significant amount of the existing defects can be erased or eliminated. How much of this defectiveness has been reduced, or, under given circumstances, can be reduced, provides a quantitative measure of the amount of existing defectiveness.

Counting the number of defective goods on the market is another tangible way of estimating the amount of product defectiveness. Many of our appliances and household gadgets, even the more permanent house plumbing, is delivered defective or in need of inordinate amount of repair. Newspapers are replete with stories about substandard products, military products which had to be further reworked to meet contractual requirements, delayed shipments, and shipments damaged in transit. One article claims that returns on furniture equalled 18 percent of sales in 1966.²

Strong, publicized evidence of defectiveness is indicated by the automobile industry's recall of new cars because of the possibility of safety defects. Rugaber reported that in the past eight years over 9.2 million automobiles and trucks have been recalled, an average of about one out of every six produced.³ The statistics may be misleading since only a small percentage of cars called in may have the safety defect in question. However, a large percentage do have minor or inconsequential defects subject to adjustment or replacement by the dealers. We can conclude that defectiveness hangs like an ominous cloud over the consumer.

Unhappily, no attempt has been made to bring this material together in a comprehensive, quantitative measurement of defectiveness. Best guesses range between 5 to 10 percent of product costs. While these guesses are loose and unscientific, they show that there is a recognized awareness that defectiveness exists and is important, and that its dimensions are a question mark.

The condition of products reaching the consumer is a third way of estimating the amount of product defectiveness. Much of the tangible evidence of the extent of defectiveness comes from Consumers Union and Consumers Research, which have been providing unbiased scientific test results on consumer products for more than thirty years.⁴

Although we have advanced from the days of the Hundred Million Guinea Pigs, unsanitary, unsafe, and unsatisfactory products still flood the consumer market. Each year CU and CR disclose substandard products of all types, safety hazards in various electrical appliances, important instances of common foods not meeting minimum sanitary standards, and hazardous mechanical products. Most of these deficiencies can be avoided, as they are found in the leading products in each line. The various deficiencies at the poorer end of the scale, however, must be evaluated not only in terms of their acquisition cost but also with respect to maintenance and possible corrective actions. Neither of the consumer testing agencies estimate the total defectiveness in the marketplace. They simply show that a great amount of defectiveness exists, that the consumer can get more for his money than he usually does, and that his greatest need is knowledge and education. In the absence of comprehensive information on the cost of defectiveness, efforts in the field of consumer education are likely to have only limited impact.

Percentage of defective incoming supplies has several economic impacts. The key is adequate record keeping of product quality. Admittedly uneconomical for individual consumers, it certainly pays off for large industrial purchasers. Most maintain records of the quality of material, purchased as determined by their own incoming inspection or from their suppliers' records. These data typically provide the basis for the vendor rating schemes used by most companies to control the flow of products to their assembly lines and to weigh their purchase decisions.⁵

A wealth of information on defectiveness is obtainable from their sources, for example, the records of 35 million parts purchased from 458 companies show:⁶

277 companies supplied parts	0 to	1.99 percent defective
39 companies supplied parts	2 to	4.99 percent defective
31 companies supplied parts	5 to	9.99 percent defective
44 companies supplied parts	10 to	19.99 percent defective
36 companies supplied parts	20 to	49.99 percent defective
31 companies supplied parts	50 to	100 percent defective."

On the average, 1.95 percent was found defective, but the spectrum of defectiveness was enormous. Most suppliers fell between 0 and 2 percent; but nearly one-third exceeded 10 percent; and over 6 percent

exceeded 50 percent. The collated records of thousands of companies would reveal essentially the same general trend: the average range of defectiveness of incoming supplies ranges between 1 and 3 percent, with too many companies soaring to inordinately higher levels. Obviously, the reduction of defectiveness is of nominal concern to some organizations, but, fortunately, vital to many others.

Reports of test activities doing public service is another source of defectiveness information. The D. C. Inspection Auto Service is an example. It reports that 23 percent of the new 1966 automobiles failed to pass the D. C. inspection on the first try.⁷ In the previous year, 20 percent of the 1965 cars failed. New Jersey and Delaware, the only other state-operated automobile testing activities, report similar rates of rejection. Most of the defects were superficial, arising from poor workmanship or faulty adjustment of headlights, rear lights, and similar items. However, the serious brake problems and even more serious steering problems caused alarm. Workmanship was the primary fault, but, in some cases "engineering faults" were to blame.

Unfortunately, none of these five signs of defectiveness is really solid or scientific. No matter how careful the count or measure, there is no assurance that we might be nearing an accurate approximation. Moreover, since our standards are constantly changing and becoming more exacting, we look more intensively at our products and find more defects. Further, the elimination of defectiveness is a reflection of improved utilization of labor, materials, and equipment aimed ultimately at increased productivity which together tend to be self-generating.

"Gold in the Mine"

Juran defines "gold in the mine" as the total of avoidable costs.⁸ It is evaluated by asking what present costs would disappear if all defects disappeared. He classified costs as tangible and intangible: tangible factory costs—factory accounts, material scrapped or junked, etc.; tangible sales costs—sales accounts, seconds, complaints, guarantees, etc.; intangible costs—delays, loss of goodwill, etc.

Juran goes on to say, "the 'gold in the mine' usually lies between \$500 and \$1,000 times the number of productive operators. In other words, a company employing 1,500 productive operators and having a total 'gold in the mine' below \$750,000 per annum is well below the average of industry, generally. If the same company had a total of 'gold in the mine' exceeding \$1,500,000, the comparative quality losses would be well above the average in industry generally."

Feigenbaum proposed an accounting calculus of quality costs that many companies now practice or have tried in the past.⁹ He divides quality costs into three categories: Prevention costs keep defects from occurring in the first place and include such elements as quality control engineering and employee quality training. Appraisal costs provide formal evaluation of product quality and include the expenses for maintaining company quality levels through inspection, test, evaluation, and quality audits. Failure costs are the result of defective materials and products that do not meet company specifications and include such elements as rework, scrap, field complaints, and spoilage. These failure costs are like Juran's "gold in the mine" and include both his tangible and intangible costs.

Feigenbaum continues, "In the absence of formal nation-wide studies of these operating quality costs in various businesses it is impossible to generalize. However, it would probably not be far wrong to assume that quality costs may represent about seventy cents out of every quality cost dollar, and that appraisal costs probably range in the neighborhood of twenty-five cents. In many businesses, however, prevention costs probably do not exceed five cents out of every quality cost dollar.

"In a nutshell, this cost analysis suggests that we have been spending our quality dollars the wrong way: a fortune down the drain because of quality failures; another large sum to support a sort-the-bad-from-the-good appraisal screen and try to keep too many bad products from going to customers; comparatively, nothing for the true defect prevention technology that can do something about reversing the vicious upward cycle of higher quality costs and less reliable product quality."¹⁰

From surveys of quality costs in American industry, Feigenbaum has concluded that quality costs may run as much as 10 percent of total cost of U.S. goods and products, or about \$50 to \$60 billion a year

Of this sum, he believes that at least a quarter of the total can be saved by substituting prevention for failure costs. That is, from \$12 to \$15 billion a year could be salvaged. A sum as large as the entire Defense Department appropriation for research and development in 1966.

An annual saving of \$15 billion equates to 15 million productive employees on the basis of Juran's top estimate of \$1,000 "gold in the mine" saving, and to 30 million productive employees on the basis of his lower estimate of \$500 per employee. These estimates are, therefore, in the same ballpark.

Europe might save between \$6 and \$7 billion through the use of statistical quality control according to Turello.¹¹ He figures that if the European gross national product is \$423 billion, 10 percent was due to the cost of quality in the three categories of prevention, appraisal, and failure costs. About one-sixth of these costs could be saved through the substitution of prevention methods for failures. Thus, of the \$42 billion in quality costs, approximately \$7 billion might be "saved through proper methods."

Apparently, Turello and Feigenbaum both assume quality costs are about 10 percent of the gross national product. Their difference in what can be saved by better defectiveness control (one-sixth for Turello and one-fourth for Feigenbaum) are minor. It is worth noting that these estimates, in a real sense, extrapolate the individual saving from a single plant to a national saving by straight multiplication.

More specific estimates of quality costs were cited by Nambo,¹² Chairman of the Central Quality Control Committee of the Nippon Kayaku Company Ltd., Tokyo. Records, kept since 1957 in each of its twelve plants, show that quality costs have run from 1 percent to 9.4 percent of total production costs. The elements of quality—failure, appraisal, and prevention costs—varied widely from plant to plant: failure costs, from 10 to 31 percent; appraisal costs, from 12 to 75 percent; and prevention costs, from 2 to 54 percent. The variations very likely reflect the different kinds of products among the plant and heterogeneity in training, local management point of view, of recording costs as precisely as possible on a plant-by-plant basis.

Eliminating Defectiveness by Incentives

Incentive wage systems, especially in the American clothing industry, have stimulated savings through the elimination or prevention of defectiveness or from the improvement of production processes. Productivity wage increases in the automotive industry have helped, too. Both incentive plans depend, to some extent, upon savings achieved. Profit-sharing plans are on the upswing. They are an attempt to provide an incentive for workers to make their products really effective. Value engineering programs and suggestion systems to help give visibility to causes of defectiveness are gaining popularity.

To recapitulate, we can say that little is known authoritatively about defectiveness. Fragmentary records of the reduction of defectiveness exist from a variety of sources. They represent the results from zero defects, value engineering, and quality control programs, which are keyed to cutting down on the rate of defectiveness or improving the effectiveness of products. The records are also available from market reports, consumer services, and systematic company accounts of suppliers' products. These fragmentary records, however loose they are, are enough to show that defectiveness is a major problem of modern society. But these records do not really tell us much more than that defectiveness exists. They provide a kind of quantitative cloak in which to hide our essential ignorance.

More Rigor in Definition

Our ignorance of defectiveness arises, in part, from an inability to define the terms rigorously. This fact has not restrained people from writing about defectiveness. Many articles on the definitions of defects and defectiveness and its related concepts appear in the technical quality control literature.¹³

Briefly, defects are rigidly defined in relation to some established standard. The number and kind of defects, obviously, are different if a different standard is used. The scale of defects, either in terms of percent defective, fraction defective, defects per hundred units, or any other reference, has meaning only with respect to those standards. These definitions and measuring concepts have great applicability in the fields of

acceptance inspection and control, but they do not dispel our ignorance on the wider defectiveness front. Therefore, in the absence of commonly accepted standards, the quantitative measure of defectiveness, as such, cannot be attempted.

What Happens to the Savings?

The savings that accrue from defect prevention or elimination at the plant level are measurable directly in dollars. Cutting costs of scrap or rework, decreasing labor, and reducing material requirements are accepted techniques for realizing savings. If Feigenbaum, Juran, and Turello's estimate of "gold in the mine" was used, the costs of producing the goods and service would be reduced by nearly \$15 billion. If this saving is considered a decrease in the gross national product, it implies that the amount of product defectiveness has been replaced by an underutilization of resources in the same amount. One type of economic loss replaces another. However, if the saving is replaced by \$15 billion worth of other products or services, thus retaining the gross national product at the same level, there is a net positive national gain as well as improvement in the products.

The replacement of costs saved for product made is through the cost-price mechanism with which the savings in defectiveness are supposedly reflected in lower costs and prices, and a corresponding increase in quantity. Correspondingly, if the \$15 billion "gold in the mine" represents improvement of product without a reduction in cost, no change will be reflected in the gross national product unless there is some corresponding change in the relative marginal utilities of goods arising from the change in defectiveness. This reasoning suggests that the gross national product does not reflect the increase in quality arising from the elimination of defectiveness.

It appears possible that the reduction of costs from decreasing defectiveness can benefit the nation, not exclusively in any money sense, but in the form of replacing effective goods and services for the defective; that is, by adding to the total amount available. More precisely, the nation as a whole profits from the elimination of defectiveness by having access to improved products and services at less cost.

Broader Issues

Our data tell us that some part of the goods available on the open market are defective. Beyond these, we surmise that some of the means of production are also defective, and that some of our designs and plans are defective as well. When we try to estimate the extent of defectiveness in the area of production and of future goods, we see how limited our understanding really is.

Defectiveness in the means of production suggests that labor and materials are being used inefficiently. More specifically, the criticism would encompass machines that could not hold the desired tolerances, equipment that will neither work efficiently nor without creating defects, labor not properly skilled for the job or deficient in education. All of these are true impairments to producing effectively.

Defectiveness designs and plans are demonstrated by the many beneficial suggestions urging the substitution of one design or an improvement for a poorer one. Nevertheless, many designs rendered substandard by later developments are still being used for the production of products, houses, ships, and the like. These substandard designs cast the shadow of defectiveness on the future. So do inadequate plans—plans either to meet the needs of the society or to obtain full utilization of resources.

The effect of defectiveness is further compounded by the consequences of the defects. The most common effect is described in terms of replacement costs: 5 percent defects are akin to 5 percent of the cost of production. Aside from the cost alone, another important consequence of defectiveness is possible damage or loss of life. A defect in the steering mechanism of an automobile is important not because of the dollar cost involved but because of the possible loss of life from an accident it causes. Similarly, it is not the cost of the rubber in a tire that counts, but the possible consequences if it should puncture at high speeds. The fact that numerous people lose their lives from automobile accidents every year in this country is a sad commentary on defectiveness. The capitalized expected earning of those killed in automobile accidents approaches \$3 billion per year, a substantial proportion of the "gold in the mine."¹⁴ However, incorporating economic consequences in the analysis only makes the job of measuring defectiveness even more difficult.

Summary

Of this we are sure, defectiveness represents a sizable drain on every company—and on the economy as a whole. Numerous American companies have developed programs for eliminating or reducing defectiveness. Each program has reported reduction in rework or scrap, reduction in time delays, and improvements in quality. The majority have claimed success in the sense that the cost of these programs has been less than the potential gain. Our interest is not so much in the techniques of these programs as in pointing up economics of defectiveness—how much "gold in the mine"—and the great difficulty in defining, understanding, and measuring it.

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QUALITY THROUGH FUNCTIONAL PLANNING

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The most important objective of any company is to make a profit. Failure to make a profit over an extended period can create uncertainty in the minds of customers and reduce the chances for the company to survive and develop. Realization of profit may be reduced to three basic and equally important elements: (1) keeping costs to a minimum; (2) meeting delivery schedules; and (3) satisfying the customer requirements for and expectations of quality and reliable products.

Essentially, this paper describes what upper-level management must do to assure itself and its customers that its products and services meet customer needs and requirements. Management, furthermore, must do the job in a manner consistent with overall company plans and objectives. This topic demands an understanding of the total quality system, which can be defined as:

The sum of the contractor's defined actions, regardless of organization, whose goals are to ensure attainment of product quality requirements and the satisfaction of product-related contractual requirements by all functions contributing to the quality of the product.

Quality objectives can be realized only if management clearly establishes certain basic principles and guidelines regarding the quality function. It is presumed that management is vitally and purposefully concerned with quality and is thus interested in arranging its affairs so that quality objectives, in addition to the others, are realized. Some of the principles that might provide a useful frame of reference in planning and managing the quality function include the following:

- Each individual must be responsible for the quality of his work, and each supervisor must be responsible for the quality of work performed under him.
- Attainment of a quality product depends on the actions of most elements of the industrial organization.

- The actions of these elements must be planned, coordinated, and managed.
- While it may not be advisable, or even feasible, to assign total responsibility for product quality to a single organization, a single organization should have the responsibility for coordinating the company's quality activities and assessing the end results.
- All personnel in the company organization must be motivated through adequate training, knowledge of the job they are doing, and an understanding of the degree of excellence expected of them to do their job right the first time.
- Direction must be clear, complete, and forthright, e.g., drawings, specifications, and work instructions are most essential.
- The design and manufacturing activities must continually adjust to discrepancy reports received from customers in an expedient and responsive manner.
- Upper-level management must give full support to the quality organization with well defined responsibilities. A weak or poorly supported quality organization is little better than having none.

These principles, which are representative rather than comprehensive, are fundamental, and must be accepted if management for quality is to be effective. The real issue—and the real test—is putting these principles into action, knowing that they are actually working in the company, and getting the desired results.

As in any good organization, there are four elements needed to manage for quality: organization, planning, implementation, and assessment.

Organization

During the past few years, the precept that "quality is everybody's responsibility" has become more accepted. Although this precept is unquestionably valid from a philosophical viewpoint, total acceptance of it without a single strong guiding and directing control is analogous to "everybody rowing the boat, with no one steering."

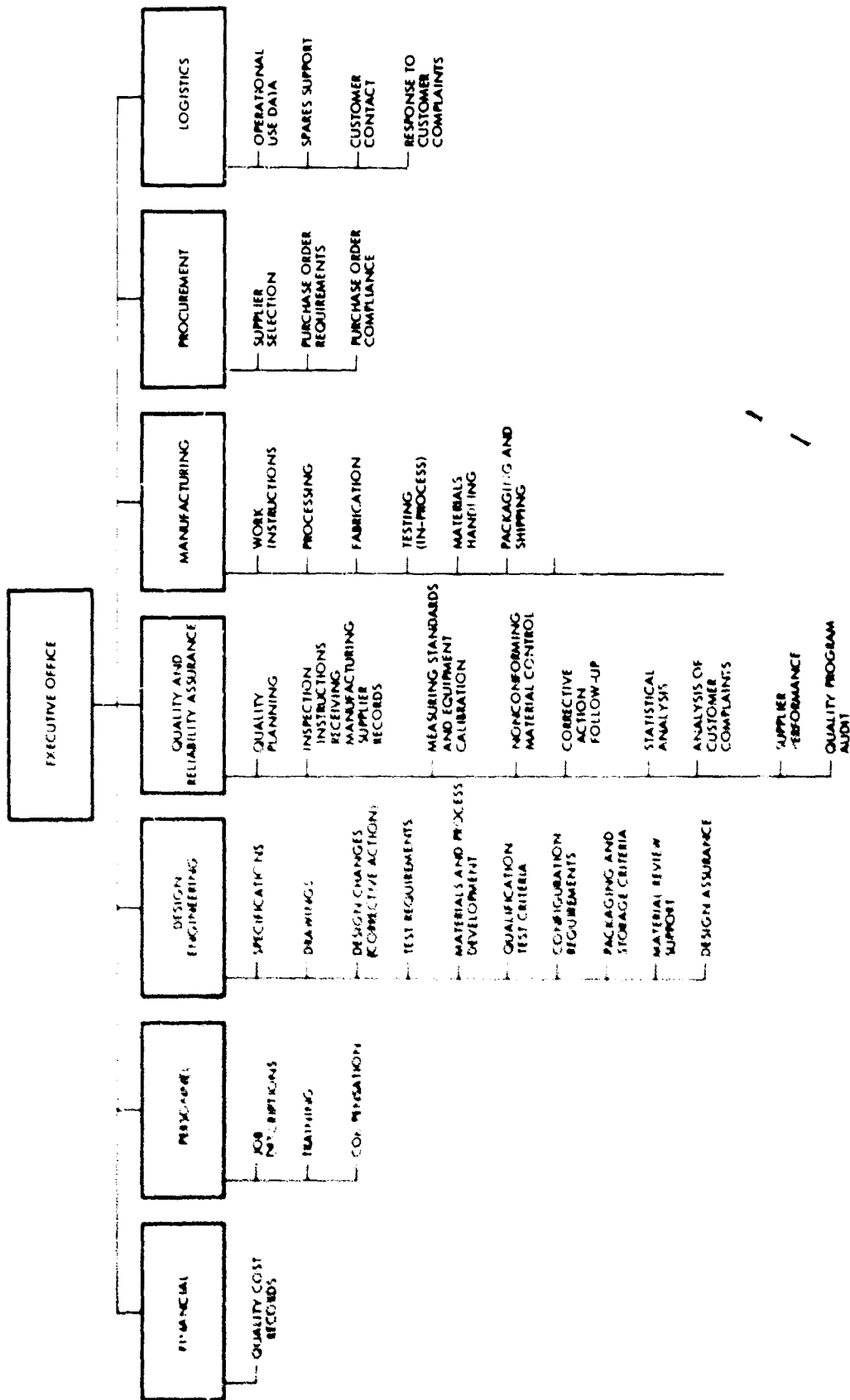
As long as the delivered product satisfies customer requirements and performs well, the quality organization which monitored product compliance with the requirements receives little attention. However, should the product fail to perform as desired, severe criticism is leveled at the organizational unit responsible for ensuring product quality.

Therefore, if management seriously intends to achieve its product quality and reliability objectives, the quality responsibilities of all contributing functions must be clearly defined, and the singular responsibility of ensuring compliance placed with the quality function that acts on behalf of the company. But organization alone, without capable personnel, cannot successfully meet the quality challenge. Conversely, capable people, when poorly organized, may well account for equally unsatisfactory results.

The following figure shows a hypothetical organization structured to have a significant effect on the total quality effort. The functions shown and the tasks delineated are by no means all inclusive but represent most of the elements to be considered in defining the total quality system.

Identifying the elements that comprise a quality system is an essential step. An equally important step is the clear assignment of responsibility for each quality task. Each company must recognize its particular needs and products, and must organize accordingly; the following figure could act as a general pattern. However, a quality organization structured for one company may be completely unsuitable for another. No matter the organization, to implement the quality system effectively, each required element must be assigned within the company, and each assignment must be clearly understood with respect to purpose, intent, and specific authority.

QUALITY PROGRAM FUNCTIONAL RESPONSIBILITIES



Quality Program Functional Responsibilities

Planning

Quality production is always expected but not always attained, and a company's reworking of detected discrepancies is no substitute for quality planning. Successful quality planning requires that potential sources of quality degradation be identified. Positive steps must be taken to ensure that such sources are eliminated. Although detailed planning is the responsibility of the conventional line organization similar to the one in the figure on the following page, it is essential that the quality organization have a part in the planning. It must clearly identify those factors that will have a degrading effect on the quality of the product and ensure that the plan contains the necessary preventative actions to be taken.

Planning for quality derives its strength from the total results of planning in quality assurance, design, manufacturing, procurement, finance and personnel. Each contributes to the total quality system.

Quality Assurance

Quality assurance planning, with respect to the total quality system, is on a par with engineering's responsibility for product design, and manufacturing's for fabrication. Physical inspection of the product and preparation of associated instructions and records must be carefully planned. Detection of deficiencies must be followed by control of the nonconforming material and prompt and effective corrective actions to ensure that the cause for deficiencies is identified.

Quality assurance participation commences at the earliest practicable phase of the engineering design effort. Frequently, that early phase is the preparation of the proposal. Elements for consideration include quality assurance provisions in material and process specifications, participation in design reviews, special environments, tooling, test equipment, processing equipment and controls, employee certification and training, special skills, unique work instructions, acceptance standards, special calibration standards, precision measurement, nondestructive test techniques, and any other area that influences product quality. Unless these contributions are made and the necessary controls developed early in the program, it is almost certain that the quality assurance will lag.

Design

Engineering designs and documents are major contributors to product quality. The beginnings of the quality program include: proper selection of materials and components; clear, well-defined drawings; design of products that can be maintained, readily assembled, and inspected; and complete and accurate material, process, and test specifications that adequately portray requirements so that performance controls can be established.

Drawings and specifications, the principal products of an engineering department, are of most use to other functions within the company and to customers. These documents must be of the highest quality because they have such a multiplying effect on product cost, schedule, and quality. Engineering must ensure the quality of its drawings and specifications just as the quality function ensures the quality of the delivered product.

The design quality assurance includes design reviews, adequate checking, designer training, feedback of drawing and specification discrepancies, and prompt corrections. Quality assurance is the major single source for identifying inadequacies in released drawings and specifications. Engineering must respond promptly to requests for corrections and seek the help of quality assurance, manufacturing, and other functions to produce the best possible designs and documentation.

Manufacturing

While most discrepancies occur in manufacturing, they are not all caused by the factory employee. Some originate upstream in design and documentation. However, such manufacturing responsibilities as adequate guidance, work instructions and training, employee motivation, proper and sufficient tooling and handling equipment, correct storage environments, and adequate packaging help prevent product degradation at the factory level. Proper and complete planning and recognition of the importance of these responsibilities cannot be overemphasized in the production of quality parts at minimum cost and on schedule.

Procurement

Materials, parts, and assemblies from suppliers are potential sources of trouble in the quality control. Just as the ultimate customer expects to receive a quality product, the company must insist on and require quality performance from all of its suppliers. A close working relationship and understanding between design engineering, procurement, and quality is essential if adequate requirements are to be included in purchase orders, responsible suppliers selected, and compliance with requirements ensured. Selection of a capable supplier on the basis of past quality performance or as the result of a source survey by quality assurance and procurement is by far the best guarantee for buying quality products at the right price and on time.

Often, the supplier is given a definitive procurement package too late in the program schedule to build and deliver a quality part. It is most important that procurement time its purchase-order-release schedule with the progress of the design to give the supplier the maximum time to do the job. Time is extremely important to the supplier since he rarely has ready access to the same design and quality assurance personnel as does manufacturing when company-designed parts are built in-house.

Financial Planning

The success of managing a quality program is measured by the quality of the delivered products and the cost of the controls necessary to ensure the quality. In this evaluation, financial planning plays an important role. Quality costs are often interpreted as only those costs incurred by the quality organization; this is a narrow view of the actual scope of the total quality system. If sound management decisions are to be made regarding the extent and adequacy of the quality system, then both preventive and corrective quality costs enter into the total cost of the system. Preventive quality costs, for example, should include those of planning, preparing inspection instructions, equipment calibration, test equipment certification, review of engineering specifications and changes, supplier surveillance, and other similar items.

Accumulation of data that reflect the cost of discrepancies and their corrections in the quality system is equally important if a company is to evaluate all factors to improve the margin of profit. Material spoilage and rework, reinspection and retesting of reworked products, changes due to engineering errors and poor design, warranty costs and products returned by the customer are typical corrective cost elements. When collated and presented to management, preventive and corrective quality costs will enable objective decisions to be made for reducing total product costs.

The accumulation of costs must be done in the least expensive manner. If the expense of accumulating costs is more than the value received, then perhaps they should not be gathered, or should be collected in a less expensive way. Costs that are expensive to identify can very often be estimated or sampled with the end result being sufficiently accurate for the intended purpose.

The important point is that the company must know the costs associated with discrepancies during receiving, fabrication, and warranty periods to properly allocate or adjust its resources for the quality assurance activities.

Personnel

Although functional management is responsible for establishing the qualification and skill requirements, the personnel organization must expeditiously acquire personnel with the specified capabilities.

Training is an essential element in the implementation of the quality system and is usually conducted by personnel. Functional management must identify those areas where special training is needed and assist in developing the training program. Early identification of training needs is important to avoid the high cost of mistakes made by employees before they are familiar with their job requirements. By nature of their functional assignment, quality assurance management should identify those areas in which special training would be required for product quality.

The inspector is the mainstay of quality control. He looks, tests, judges, and accepts. The inspector's job must not be diminished in stature or importance in spite of continued emphasis on analysis, quality engineering, and planning. Because inspection decisions have a direct and substantial effect on costs and schedules, they must be made by trained and experienced men who know they have the full backing of management. Inspectors should be audited and tested to be certain there is consistency in the standards of acceptance and that the drawings, specifications, and procedures are thoroughly understood.

In companies where the percentage of technical talent is high and the products have a high performance content, the quality assurance function must have an adequate core of technically trained men if quality assurance is to communicate on technical terms and issues with the design engineers. Quality engineering is now a universally accepted profession. Colleges are already awarding degrees in this field and many others have indicated plans to do so in the future. The salary of these engineers must be comparable to the design engineers if capable men are to be attracted to and retained within the profession. The quality engineer should provide technical assistance to the inspector, participate in design reviews, review material and process specifications, and interface with the design engineers.

Implementation

Even with carefully structured organizations and thorough management planning in the contributing functions, the success of the quality system depends primarily on the conscientious implementation of the plans. Those organizations identified earlier in this paper that have a significant effect on the quality of the product must clearly and fully understand their responsibilities. The quality system has a far better chance of effective implementation if top level management supports the quality assurance organization and reaffirms its total authority over the quality of the product.

The chief engineer, the manufacturing manager, and the procurement manager, by their expressions and emphasis on quality work, set the pattern for personnel in their departments. Quality work must be

done without establishing "empires" that do not contribute to the total company effort. The responsibility delegated to the quality assurance organization as the prime coordinator in the attainment of quality should be recognized throughout the company and should not be challenged.

Assessment

When adequate effectiveness is realized by all of those contributing to the quality system, the policing role of the quality assurance organization would be reduced. Because the responsibility for quality of design rests with design engineering, and the responsibility for quality in production rests with manufacturing, satisfactory accomplishment of these responsibilities will provide the required quality at the lowest cost. Unfortunately, experience shows that recognition and acceptance of responsibilities do not always ensure effective results. For this and other reasons, a strong quality assurance organization that includes an independent and continuous assessment of the total quality system is essential.

An assessment or audit of adherence to product quality requirements will not in itself be an effective tool unless two conditions are considered. First, specific and realistic criteria must be established for all phases of the quality system to be subjected to survey and evaluation. That is, there must be an audit plan. Second, a complete follow-up to correct and resolve any identified problem areas must be made a recognized part of the assessment effort. Judgments of performance adequacy based on the established criteria must be made to determine whether improvements or changes are necessary in the areas of quality costs and product acceptability.

Summary

Many of the actions and interplays between functions described in this paper have been practiced for years within most successful companies. Had they not, the United States would not be so great an industrial nation. Organization alignment has not been a major point in this paper. But top management should seriously consider that the organizational position of quality reflect the importance and authority given it to both the customer and other functions within the company. Regardless of the organizational aspects, the attainment of quality levels that will satisfy the customer and still be competitive will depend on good management practices, the adequacy of procedures, availability of data on which to make decisions, and a quality-minded organization.

"ZERO DEFECTS" TYPE PROGRAMS—BASIC CONCEPTS

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The creation and distribution of satisfactory products and services are the outcome of intensive and comprehensive management attention to key industrial functions; particularly design, development, procurement, production, quality assurance, and maintenance. Many managers in both government and industry feel that while attention to these basic elements is essential for assuring product quality and customer satisfaction, it is also advantageous to mount a special effort—a clearly defined and identifiable program—aimed at marshalling the support of all persons in the organization in a unified effort to assure that products and services of high integrity are generated, costs are restrained, and customers are kept happy.

While such special programs can take various shapes and forms, there has emerged in recent years a specific kind of program that has proven effective in eliciting employee support. This program has led to a continuing effort to turn out products and services that truly satisfy consumer needs. This type of program is motivational in nature and is identified by a wide range of titles, such as "Zero Defects," "Pride," "DO GOOD WORK," "V. I. P.," etc.

It is the purpose of this paper to review the nature of such programs in terms of their essential elements—building blocks, so to speak. All of these programs will be considered under the generalized "Zero Defects" title. This paper also attempts to answer the questions:

"What is Zero Defects?"

"What are its objectives?"

"What are the necessary steps that must be taken to organize and implement a successful program?"

Zero Defects—What It Is

While Zero Defects programs might appear on the surface to be a re-hash of worker motivation programs that appeared during World War II, there is a more clearly defined methodology and technique emerging in today's programs. Today's manager is taking advantage of the findings of the more than 30 years of research in the behavioral sciences, including industrial psychology and sociology.

Zero Defects programs appear to be the first major large-scale effort by management to deal in an organized and planned way with employee motivation. The concepts of this function are in a state of emergence from the research findings of behavioral scientists which began to influence management's thought as early as the 1920's.

Whether in industry or government, Zero Defects programs might best be described as organized efforts instituted and directed by management to inspire all persons at all levels in the organization to do the job assigned them as precisely as possible. More directly, these programs are organized efforts to motivate people to "do their job right the first time—every time." Such programs represent a major shift of emphasis from detection and elimination of defective products and services to prevention of such defective products and services. The important consideration is that these programs must be instituted and directed by management in cooperation with all strata of the industrial organization.

Such special programs have not come about by accident. They have evolved in industry as responses to real problems, problems that are experienced by both managerial and nonmanagerial levels. For example, Zero Defects is a response to the problem of screening, reworking and failure in manufacturing operations. It is cost reduction. Equally important, Zero Defects is a response to employee feelings of anonymity by providing a mechanism for transmitting intelligent and constructive contributions which they feel will enable the organization to better achieve its goals and objectives.

Zero Defects — What It Is Not

It is essential to emphasize that Zero Defects programs do not have as their purpose speeding up production or compensating for management oversights. Such oversights may pertain to communications, planning or any other prerequisite for effective work performance. It is also important to emphasize that Zero Defects is not aimed at perfection per se. By attempting to minimize the occurrence of errors by means of a formalized structure for effecting employee cooperation, a kind of understandable "perfection" is in fact attained. It might be said that all persons in the organization are attempting to achieve perfection, not perfectionism. The aim is not to create the "infallible" person but to reduce fallibility. It is also improper to assume that Zero Defects is some sort of panacea. This notion suggests that if an industrial or government organization installs such a program, its quality program will soon evaporate. Unless the organization has carefully developed a quality program, no amount of emphasis on special programs will compensate for this deficiency. In other words, ZD assumes the prior existence of adequate and proper quality control.

Why Initiate a Zero Defects Program?

As mentioned earlier, management may choose to organize a special program of employee cooperation to enhance an already effective manufacturing or service operation. However, this is not usually the case. In most instances, management operates in an environment in which decisions are made and action is taken to counteract those exceptions to effective operations. In other words, management responds to existing or potentially destructive or unprofitable forces that it sees developing in the organization. Circumstances that may lead management to consider a Zero Defects program include:

- A negative change in the productivity rate. This would indicate that the organization is dropping behind similar companies in industry.
- Increase in product costs with no apparent, measurable, or tangible cause.
- Indications of potentially destructive informal group influence causing organizational orientation away from defined goals and objectives.

- Indications of employee dissatisfaction (pilferage, higher than average turnover rate, increased tardiness, abuse of sick leave and vacation privileges, increased number of employee grievances, etc.).

Of course, there are more positive indicators to which management is exposed every day in a very real and tangible sense. Such indicators that may cause management to mount a formal employee participation program are: decline in product quality and reliability as measured "in-house"; increased customer complaints; greater number of warranty actions; stack-up of inventory with a decline in working capital; change in credit policy of suppliers (vendors); and increased scrap and rework cost. Each organization places a different emphasis on the various indicators that tell management "how we are doing." When those indicators call for some kind of management action, the solution may be in mounting a Zero Defects type program.

Objectives

When a program is initiated, it is necessary to define clearly and understandably those objectives which the organization hopes to achieve. Without positive identification of objectives, no individual or group or organization can hope to achieve fulfillment. If a goal or objective is not recognized, how can it possibly be attained? The objectives of Zero Defects might conveniently be classified into two categories: immediate and long range.

Immediate Objectives

When a Zero Defects type program is initiated, its immediate objectives are to obtain understanding by all persons of what is being attempted and to obtain cooperation by all persons in intensifying their attention to the details of their work. It should be stressed at this point that the term "all persons" is not limited to shop workers. Equally important is the cooperation of management, engineering and technical personnel whose work more often than not can have a greater impact on quality than the routine action of those involved in production or fabrication jobs.

Basic Elements

Like all special programs, Zero Defects has three basic elements: planning, implementation, and follow-up. Planning embraces the visualization and determination of any array of future actions that will lead to the realization of desired results. It is the consideration and establishment of related facts and assumptions in advance which enables management to design the chosen combination of actions that will result in a successful Zero Defects program. In order to visualize and choose among alternative courses of action, it is extremely important that management assemble, relate, consider and establish all known facts and assumptions relative to the situation. Meticulous attention to the planning function is extremely important in developing a Zero Defects program.

The manner in which plans are implemented (the second basic element) reflects the effectiveness of the planning function itself. The initial response of all persons to the Zero Defects program is management's first indication of the effectiveness of that planning and implementation and dictates the nature, extent and magnitude of attention to the third basic element, follow-up, including program improvement and adjustment. Each of these three basic elements is discussed below in more detail.

Planning

A plan for a Zero Defects program of necessity takes account of the following pertinent considerations:

- The particular objectives of the program in a specified industrial setting.
- The establishment of specific goals, preferably in a quantitative form.
- Development of procedures for measuring progress toward those goals and the formulation of procedures for eliciting employee involvement in the program.

Unless these considerations are carefully probed prior to initiation, it is not likely that the program will be a success. Such planning is understandably the most decisive element in determining the success or failure of the program.

In relating a program plan to a particular industrial setting, it is advisable that extensive and thorough consideration be given to assuring that all areas within the organization will derive adequate benefits from the program. An effort should be made to pinpoint the departments, shops, processes, products and services that are likely to yield significant rewards. The identification of these prime targets may be made on a preliminary basis through surveys or questionnaires to determine current rates of defectiveness and related costs.

These areas of opportunity have been pinpointed. The program plan should make provision for formulation of progress milestones in quantitative terms. This may be established on a percentage basis or in pure numerical terms utilizing feed-back data from existing management control and reporting systems. In any event, failure to consider all possible alternative courses of action relating to accomplishing the objectives of the program will result in establishment of a program characterized by preachment rather than solid achievement.

Once the objectives and quantitative program goals have been established, it is necessary to develop procedures for measuring progress and eliciting "total involvement" of all employees. To assure this kind of involvement the program plan must take into consideration the following action areas: participation; performance measurement; knowledge of results; recognition; communications; publicity; and work research.

Participation. The opportunity for each employee within the organization to participate in the direction of the affairs which affect him and his work situation is of primary importance to the program. The program must make provision for participation in both breadth and depth or degree. By breadth is meant the involvement of all personnel from the lowest level in the organizational hierarchy to very top management. To be effective the involvement of individuals should be more than superficial. The employee of today is far too sophisticated to be "taken in" by efforts to obtain his support without an opportunity to share in the decision-making process. In this case, the decision of self-commitment to higher goals and goal levels themselves are pertinent.

The greater the depth of participation on the part of the employee in that goal-setting process, the more total his commitment to the program. Employee support is closely tied to the degree of employee involvement.

Performance Measurement. The method of measuring performance is most effective when developed by the group of the specific operation involved. This suggestion makes use of the previous element, participation. The standard selected should (1) reflect quality (as opposed to quantity or productivity), (2) be relatively easily measured, and (3) be readily understood by all participants in the group effort.

To the above must be added the admonition that the measurement be not only fair but have the appearance of fairness. No matter how accurate the appraisal system may be, it is of little value if the employees do not have confidence in it.

No one criteria is applicable equally to all types of endeavor. Since the Zero Defects program involves all employees, job responsibilities vary widely; therefore, parameters must be selected with the specific characteristics of each job in mind.

Knowledge of Results. No matter how much one desires to produce effectively, it is impossible to do so unless he is informed as to the standards towards which he must strive and the degree to which these standards are met. Vital to continued interest is accurate and frequent appraisals of performance.

Once adequate and acceptable methods of performance measurement have been developed, numerous methods of informing the employee of these results may be used. The choice of the particular means is dependent upon a number of variables such as individuals, nature of the work, quality of performance, etc.

Recognition. Most individuals possess a need for a sense of accomplishment. The belief that an employee's work is important and that he is contributing to the success of the organization can be powerful motivating factors. Suitable recognition of satisfactory or preferably superior performance is a basic element of the successful Zero Defects program. For many individuals, such recognition may come in the form of salary

increases, promotions, increased responsibility, and greater status. Since the program is all inclusive and some individuals cannot attain recognition by these traditional ways, it is desirable to establish other forms of recognition. Among these are pins, certificates, prizes, sums of money, etc. Goals must be within reach; contributions must be rewarded. Such obvious recognition of an employee's worth further gratifies the need for self-esteem and approval.

The most valued form of recognition is that which directs maximum attention to the individual.

Communications. Communication "is the transfer of meaning and understanding from one human being to another." Unless this transfer has occurred successfully, true communication has not taken place. Since total acquaintance and ultimate acceptance of common goals is essential to the program, communication in the fullest sense is imperative.

If the employee is to become an effective component of the Zero Defects program, he must be adequately informed of the objectives of the organization. The role played by the individual in helping the organization to meet these objectives is determined to a great extent by the information he possesses.

In any organization, information flows upward, downward, and laterally via communication channels, both formal and informal. Enthusiasm is not generated unless the participants are kept well informed.

Publicity. Publicity, the twin element of communication, is concerned primarily with the development and maintenance of the organization image. It is important that the participant be proud to identify with the organization. The image which the employee and the community hold of the organization is largely the result of an effective publicity program. Regardless of how good the organization is, if the fact is not known or recognized, it will be of little value.

An effective publicity program must (1) be well organized and directed, (2) be designed to foster a greater awareness of company objectives, and (3) recognize individual as well as group and organizational accomplishments.

All media which lend themselves to effective use should be utilized, i. e., newspapers, radio, television, pamphlets, and point-of-contact displays.

Work Research. The mature Zero Defects program should include work research. This element is necessary to prevent stagnation. A continuous search for improved procedures indicates to the employee that the organization is interested in his welfare.

Even though the organization may have a staff group responsible for the improvement of work procedures, in no way should this eliminate the average employee from involvement. Each individual should be made to realize that his involvement is a part of his own personal responsibility. Participation in this aspect is as coveted as in any other area. Use should be made of the first six elements to derive the most value from this, the final element.

At this time, necessary promotional material must be prepared. That material for program activities must be tailored necessarily to the specific needs of the implementing organization. Promotional materials should include (1) a management letter on the Zero Defects concept and philosophy (including generic terms applicable to the program), (2) a program plan, (3) packaged visual presentation materials for indoctrination of the staff and all employees, and (4) a "teaser-type" publicity plan to arouse employee curiosity and interest.

In summation, it can be said that intensive planning and preparation are absolutely necessary preludes to program initiation. Unless adequate groundwork is laid it would be inadvisable to proceed further in the implementation of a Zero Defects program.

Implementation

The product of adequate attention to basic program planning will be a precise and comprehensive schedule for implementation of a Zero Defects program. The implementation plan serves two important purposes: (1) it provides management with a clear picture of the events scheduled and costs budgeted to implement and support the program; and (2) it gives the program administrator a set of guidelines to follow. Included in the program

plan will be some provision for demonstrating the interest support and commitment on the part of the organization's chief executives. Since this is such an extremely important prerequisite to successful program implementation it is appropriate that the role of the executive be discussed at this point.

Role of Top Management. The Zero Defects concept recognizes that even though the individual employee is adequately trained, is dedicated and uses proper tools, he does not necessarily do defect-free work. He needs something more — a reminder that his contribution to the quality of the product is important and is recognized by management. The employee can be expected to maintain a positive attitude only if his efforts are acknowledged by persons in the higher echelons of the organization. Hence, strong commitment will be forthcoming if key organization executives have been integrated into an effective team.

Management endorsement is required not only at the start of the program but throughout its subsequent stages. Prior to carrying out the first stages of program implementation it is incumbent on management to make an organization-wide assessment of opportunities for improving all aspects of operations. There is no point in implementing a Zero Defects type program unless management can identify significant targets for improvement. Possibly the most rewarding aspect of management's involvement in such a program will stem from this assessment.

Finally, it is important that some personal and visible manifestation of this total involvement on the part of key executives is provided.

Program Initiation. It is important to provide for a pre-implementation phase. This is a period of time during which positive steps are taken to build employee interest and create an air of anticipation within the organization. Activities carried out during this phase should include personnel briefings and publicity. Much effort must be expended in explaining all facets of the program to those management personnel who were not involved in the planning phase. Carefully planned briefings should originate at the chief executive level and filter down through mid-management levels to first line supervision. The "teaser" publicity campaign of

slogans, questions and other curiosity-raising means should be started about three weeks before the formal program "kickoff."

The success of activities carried out during the pre-implementation phase will reflect the adequacy of planning for "communications" mentioned earlier in this paper.

Implementation Activities. At the initial "kickoff" of the program, every effort must be expended to get across to everyone in the organization the objectives and goals of the program. An effective way to accomplish this is to conduct a company-wide rally. Representatives of management, supervisory levels, employee organizations, suppliers, customer organizations, and local public figures can be given prominent roles in the event.

A prominent, national-level guest speaker should be provided. It should be emphasized that the organization is attempting to achieve its short-range objective during this period. That is, it is attempting to obtain the understanding and cooperation of all employees so that they will commit themselves to high performance goals because they want to, not just because they are asked to.

Once the program is in operation, the primary objectives are to help the individual achieve these higher goals of error-free work and to maintain his interest and dedication at the highest possible level. This latter objective can best be met through a sustaining program that (1) identifies and eliminates the causes of error; and (2) recognizes and rewards individual and group Zero Defects achievements.

Eliminating the Cause of Errors. A procedure for identifying and eliminating the causes of errors should be included in the initial phases of program implementation. "Error-cause-removal" (ECR) is such a procedure, whereby: (1) individuals are encouraged to identify existing causes of errors or defects; (2) supervisors promptly investigate the identified problem; (3) prompt action is taken on the problems and; (4) the individuals are made aware of the action and are rewarded appropriately.

An ECR procedure may pose some management problems, particularly where the action needed to correct a condition is either more costly than the defects involved or cannot be taken as promptly as might be desired. Any apparent lack of action may be interpreted as an indication that management is not only indifferent to ECR, but is also unwilling to acknowledge its own errors. Thus, management's vital role in the Zero Defects program is nowhere more apparent than in the operation of the ECR procedure. Management must respond rapidly and constructively to ECR recommendations and must be prepared to present the factual basis for decisions made.

As a key element in the success of ECR, the supervisor must be carefully and fully briefed in the operation of the ECR process. He should also be furnished written guidance to explain the procedures he is to follow in ECR and to assist him in detecting and identifying environmental causes of error.

Recognizing Achievements. Official and public recognition of achievements is an important part of a Zero Defects program. Accordingly, procedures must be devised for identifying and evaluating those accomplishments which warrant recognition. Since a Zero Defects type program is directed primarily at motivating the individual, initial concentration should be on individual recognition. However, provision for recognition of small and large groups and the organization as a whole should also be made. Group recognition is particularly important where team work rather than individual effort alone is of primary importance in the reduction of defective workmanship.

Starting action leading to the formal recognition of Zero-Defects achievement is most appropriately part of the regular duties of each supervisor. Adequate pre-initiation planning will take into consideration procedures whereby supervisors may use existing data and records of past performance to facilitate evaluation of potential achievements. It is extremely important to assure that recognition is accorded only for significant accomplishments, and in order to do so, it is advisable to provide for review of all recognition recommendations by a formally organized

committee. This committee should be selected by the organization's top manager with careful attention to assure that its makeup will provide for objective deliberations and action that will not be subject to intra-organisational bias.

The most effective method of recognizing Zero Defects achievement is some form of personal approbation, which is usually found to be a more potent stimulant to ZD efforts than monetary or other material rewards. Group recognition provisions are valuable primarily as support elements of a Zero Defects program. Such recognition encourages team effort and engenders competitive spirit between groups. It should be remembered, however, that group recognition has certain inherent disadvantages such as the possibility of recognition of certain employees of a group which have not contributed to its success and, in fact, may be negative in their attitude. Conversely, an outstanding employee in a low achievement group may go unrecognized because his group's performance is inadequate. Thus, group recognition procedures must be used with caution. Group motivation, accordingly, also must be subordinated to motivation of the individual if the Zero Defects program is to succeed.

Follow-Up, Including Program Improvement and Adjustment

Perhaps the most revolutionary effect of ZD upon the modern business organization is that the product of its success is a tangible change in organizational attitude and a new awareness of the individual's contribution to its goals and objectives. Employees are no longer production workers. They now become creative contributors to the progress and success of the business. Individuals begin to feel their importance as vital units in the total structure.

It was mentioned earlier that a program plan should consider certain basic elements in developing an overall program. During initial implementation of a Zero Defects program, major attention is directed toward only three of these elements: participation, communications and publicity. It is during the follow-up phase of program improvement and adjustment that the organization begins to raise its sights to focus on the program's long-range objectives. It is during this period that the remaining basic elements should be integrated into the overall program.

Particular attention should be given to the element of performance measurement. As was stated earlier, such measurement should be expressed in quantitative terms, if at all possible. Such measurement is usually designed for the group and not the individual. Properly designed, this measurement can be used to illustrate more than one aspect of ZD accomplishments. It may show, for example, that the defect rate actually achieved by the group is not only lower than the defect rate that the customer will tolerate, but is also lower than the defect rate established as the goal.

Equally important during this phase of the program is consideration of "knowledge of results," of informing the individual of progress being made in an understandable way. In most cases, this can be accomplished through some form of visible display such as measurement charts or through periodic reports to all persons in the organization.

Program improvement and adjustment is also concerned with special attention to the "error-cause-removal" program discussed earlier. In this respect, initial attention should be directed toward procedures that will reduce the period between problem identification and management response. Another factor which warrants special consideration during this phase is the method by which the individual employee can identify himself with the product of his labor. This might be accomplished through special displays to allow employees to see their products in use, or arrangements to have customers who are well satisfied with the product explain to the employees the importance of defect-free products to them.

To summarize, program improvement and adjustment tries to broaden management's attention to all the basic elements of the program in order to assure that a well balanced program evolves suited to the overall needs of the organization.

Summary

A Zero Defects program requires extensive planning if it is to accomplish its intended purpose. Such a program can be expected not only to motivate employees to perform effectively, but to identify conditions that impede employees' efforts toward the achievement of error-free performance of their assigned tasks. It is generally recognized that it is more difficult to sustain a Zero Defects type program than to initiate one. If the plan to sustain interest in the program is thoughtfully and imaginatively developed at the outset, the program will be successful.

Some of the key points of the Zero Defects concept may be summarized as follows:

- Success of a Zero Defects program is contingent on sustained management interest, support and direction.
- An adequate program plan considering the organization's goals and objectives must be developed.
- A Zero Defects type program should encompass and be directed toward all personnel in the organization.
- Primary emphasis should be directed toward motivation of the individual employee.
- A well conceived plan of recognition for employees' Zero Defects achievements is essential.
- Adequate attention to program improvement and adjustment will take into consideration all of the basic elements of the program.

TECHNICAL CAUSES OF DEFECTIVENESS

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Defectiveness can be the result of many causes, singly or multiply relating to economic, personal, and technical conditions. Of these three conditions, most of the emphasis of the nation-wide Zero Defects Program has been on the technical. It is the purpose of this chapter, therefore, to discuss only the technical conditions leading to defectiveness and to analyze them in terms of four major elements: equipment specifications, design, production, and use. Corrective actions are also suggested.

Equipment Specifications

The equipment specification is the single most important element influencing the level of defectiveness throughout the product cycle. Its purpose is to define in precise technical terms all of the requirements for an end item so that, when completed, it will perform its purpose exactly as desired. The specification is the beginning and, therefore, can be the root cause of defectiveness that occurs farther into the product cycle.

While there are many reasons why a specification can lead to defectiveness upstream, six appear to be the most common to all:

1. Incomplete research and specifying of all end-use physical and human environment.
2. Failure to incorporate into the specification customer expectations and end-user performance requirements.
3. Need to extend the state of the art without adequate and necessary research and development.
4. New and advanced applications of existing equipment without consideration for compatibility and related adaptations.

5. Incomplete and ambiguous language in the specifications that encourage responsive but inadequate bids from marginal producers.
6. Indiscriminate use of subsidiary specifications commonly and collectively referred to as "boilerplate."

Usually, the equipment specification comprises documents describing the performance of the required equipment in a certain environment. Hardware, software, facilities, and personnel needed to operate and maintain the equipment economically and efficiently are also described. If the equipment specification fails to define clearly and completely all of these characteristics, the root causes of defectiveness find a fertile field for mushrooming into a myriad of defects.

Specifications, when initially prepared, represent a compromise determined by the restraints imposed by budget, schedule, performance, and limited knowledge of all facets of the problem. Consequently, the documents should incorporate feedback for corrections and improvements as experience is gained. However, the compromises must be carefully calculated, otherwise there will be false starts and, possibly, programs will have to be abandoned with serious economic consequences.

Physical and Human Environment

Insufficient research into all the conditions under which equipment will be used is probably the most prevalent and serious cause of deficiencies in equipment specifications. One technique for overcoming this difficulty is to have answers to the following questions before preparing the specifications:

Where will the product be used?

What are the physical environments, singly and combined?

Who is going to use the product?

How will the product be maintained?

The answers should lead to quantitative requirements showing the ranges and combinations of environments that are necessary if the design is to be optimized for cost and effectiveness.

Meeting Customer Expectations

As customer tolerance to traditional performance levels decreases, industry must respond by tightening its specifications. Examples are plentiful, but the most striking and recent concern is the rash of stories on defects in new automobiles. The public reaction bordered on violence and Congress reacted accordingly. That is one outcome of public displeasure with the way engineering specifications are implemented on the production line or the way they are formulated in the first place.

Another result of failure to meet customer expectations that can be even more severe and costly is his reluctance to buy the product. The publicity connected with auto safety had a measurable impact on sales. But the industry made many of the changes demanded and recovered nicely. The wood furniture industry, for instance, was not as speedy and suffered for it. It had not noticed that customer standards of acceptance had gradually increased such that recently 18 percent of the product sold (in terms of sales dollars) was being returned for adjustment. A sweeping revision of industry standards, packaging design specifications and handling criteria were instituted. Earlier action—and greater awareness of the customer's expectations—may have prevented some tragic losses.

Optimizing Maintenance and Reliability

A design specification is incomplete unless it establishes a meaningful balance between maintainability and reliability. Very quickly, the deficiencies and defects are highlighted when it becomes extra difficult to troubleshoot, isolate faults and replace components.

Examples are plentiful, unfortunately, of equipment designed with one or the other requirement—maintainability or reliability—predominant. The lack of balance created unnecessary problems in the less dominant condition. The solution, of course, is to establish the desired optimization of reliability and maintainability in the initial design specification.

Under the section on design in this paper, a number of practices are described which are causes of very serious defectiveness. The reader might find it interesting and worthwhile to determine how many of the defective design practices described in that section might have been averted if the design specifications had been more definitive.

"Leap Frogging" State of the Art

Technology, today, might be described as a rapid fire, "leap frogging" state of the art. Not long ago, single breakthroughs in technology were usual and could be absorbed systematically with relative order. Today, multiple breakthroughs occur in rapid order succession and create a severe problem in generating realistic equipment specifications.

Consider microminiaturization. Highly successful demonstrations of man's new microelectronic devices in the laboratory positively and correctly point to the widespread application in a variety of space, military, commercial, and consumer products. Defectiveness can arise through the failure of the design specification to require adequate applied research and development that will evaluate the new technology in terms of the customer's expectations. In many cases, overall evaluation and prove-out of operational suitability requires quantities of the equipment be placed into operational inventory as soon as possible. In doing so, however, the equipment specification should reflect state of the art, and provide realistic programming of the tasks required to bring the devices and equipment progressively to a point of ultimate maturity. To assume instant maturity in the equipment specification requirements only increases the risk of defectiveness.

New Applications for Existing Equipment

A major source of defectiveness has been traced to inadequate specification of existing equipment to new applications. For example, a successful producer of home washing machines decided to expand into the international market. He selected a virgin territory in which the standard of living had risen sufficiently to offer a lucrative market for his product. The nameplate and operating instructions on his standard machine were changed to the language of the new territory. Metric system dimensioning was adapted to assure a ready source of replacement parts and to allow local participation in parts production. However, his technical people had participated only superficially in the planning. Had the planning been more thorough, they would have found that the chemical and mineral

content of the water used for washing was reactive to certain finishes in the machine. This single required modification to the engineering specifications resulted in a very damaging defect in the machine and to the reputation of the manufacturer.

In another example, an airborne radar had been developed and used a number of years as a low altitude general aid to navigation. The same radar was later specified for a new high altitude aircraft as a prime precision positioning instrument. Because provisions were not made for adequate study of the adaptation, product defectiveness under the new conditions were initially excessive.

Incomplete and Ambiguous Specifications

The language of engineering specifications, in its attempt to be expressive, often confuses those without intimate knowledge of the subject. For instance, to the uninitiated, what is "good" or "best" commercial practice? In most cases, these terms are completely undefined and may be interpreted in a wide variety of ways. In one literal interpretation, "best commercial practice" could mean that use by Bell Telephone Laboratories for the underwater cable in which no failures can be tolerated for twenty years. Obviously, the same "best" does not apply to a radio or communications set which may be a noncritical application or have sufficient backup modes of communication. Other confusing terminology include: "give consideration to," "maximize," "minimize," "goals," or "objectives."

Probably the hazards of incomplete and ambiguous specifications are experienced most painfully during the procurement phase. The knowledgeable company will know what is needed. It will prepare a proposal and cost quotation that will be truly acceptable to the end user. The less knowledgeable company, being unfamiliar with the costs of the unobvious deliverables, will very likely submit a low cost design that may make it the successful—although unqualified—bidder. Both the customer and the contractor suffer. The customer receives a product that cannot perform, and the contractor gains a record and reputation for being a poor performer.

Indiscriminate Use of "Boilerplate"

Indiscriminate listing of large numbers of subsidiary specifications (boilerplate) in an equipment specification frequently results in defectiveness along with added costs. The situation becomes dangerous when critical specifications are obscurely listed along with a great many predominantly irrelevant specifications. The tendency, sometimes, is to dismiss the entire list as unimportant, and thereby miss the critical specification buried in the boilerplate.

It is particularly important that engineering specifications include only applicable portions of specifications actually needed. Frequently, the most competent subcontractor may decide not to respond to a bid request if the requirements, as cited in the mass of boilerplate, are excessively complicated to analyze and appear to increase the profit risk.

Design

From the designers' standpoint, if there are any defects in his design, it is because of restraints or limitations in available time, funding, state of the art, and practical shortcomings in information retrieval. The degree of truth in that contention varies from design to design. Certainly the uncertainties inherent in inventing on schedule must be understood by program managers and the program given sufficient flexibility to allow for unexpected difficulties. Still, a substantial amount of defectiveness is traceable to the design for a number of reasons: marginal functional design; inadequate design for ease of manufacture; incomplete analysis of design strength during manufacturing processes; and incomplete design planning for orderly growth to maturity—dynamic design requirements.

Marginal Functional Designs

Marginal components invariably lead to marginal performance. Peeking adjustments and careful handling may help pass acceptance tests, but the "golden glove" technique cannot follow the equipment to the user and performance soon drifts below specified limits.

Notoriously unreliable parts are common sources of defectiveness. Reliability experts now have much data and methodology to assist the

designer in system synthesis and analysis. From the possible candidates, effective solutions and associated parts may be selected to optimize the systems and cost effectiveness.

Designs may be functionally defective due to the loose specification of parts or components thought to be noncritical. This is particularly true with solid state devices for which certain parameters may vary over a wide range from producer to producer, and from lot to lot. Measurement of the variation in unspecified parameters frequently provides valuable evidence concerning basic parts reliability.

Many analytical and test techniques are available to detect marginal functional designs. Computers can now be programmed to calculate or simulate functional robustness under a wide variety of conditions. Tests can be designed to verify the numerous assumptions necessary during the design and evaluation.

Inadequate Design for Manufacture

Frequently, it is extremely difficult to design equipment which is easily manufactured. Sometimes referred to as "poor produceability," the inadequacy often occurs when available state of the art must be exceeded.

Scaling. Produceability is frequently compromised by scaling old designs to meet new requirements. Mechanical and electromechanical equipment designs are the most frequent victims, along with electronic equipment miniaturization. "Scaling down" often is resorted to when tighter tolerances are demanded for increased accuracy or equipment size must be reduced to accommodate decreased volume, weight and power drain. "Scaling down" often appears to be the easiest and least costly by designers not familiar with limitations in manufacturing processes and stability of materials.

Standard Tolerances. Commonly, "standard" decimal and fractional tolerances apply when other tolerances are not specified on the drawing. Frequently, little engineering has gone into the determination to use standard tolerances and manufacturing defects begin to show.

Investigation has shown that "standard tolerances" may frequently be broadened as applied to specific dimensions so as to reduce the possibility of defective material being produced.

Other Conditions Affecting Produceability. Some other frequently encountered conditions that are causes of inadequate produceability are as follows:

1. Excessive crowding of wiring and interconnection joints causing breakage of wires and terminals
2. Poor accessibility during assembly for troubleshooting, rework, and replacement of parts
3. Use of materials and parts difficult to procure often requiring under-specification substitutions
4. Insufficient knowledge of effect of manufacturing variations in tolerances on function
5. Lack of knowledge related to adjustment and calibration
6. Poor stability and repeatability of electrical and mechanical functions
7. Undue sensitivity to dust, humidity, and other environmental decontaminants
8. Reliance on the "golden glove" technique for adjustment in assembly
9. Confusing standards for marking polarity and type on small electronic parts

Incomplete Analysis and Specification of Allowable Stresses During Manufacture

Design data sometimes do not account for acceptable levels of such manufacturing stresses as:

Temperature (soldering, welding, degassing, curing, storage)

Mechanical flexing

Electrical currents and voltages (test, troubleshooting, discharge from nylon clothing)

Mechanical shock (handling, assembly, cutting)

Magnetic, electrostatic

Humidity, gasses, contaminants

Ultrasonic vibration (cleaning)

Power Failure

Inadequate Attention to Design Details

Examples of inadequate attention to design details could fill volumes. But one example, adhesives and cements, might serve to illustrate how defectiveness can occur through oversight. Selection of these materials is frequently considered routine and given little attention. However, many supporting materials are surprisingly active chemically when used with, for instance, the plastics. If adhesives and cement are to be used, the designer would be wise to call in the materials expert for consultation and design review. Chemical actions and vapor depositions are frequently accelerated when sealed assemblies are evacuated and degassed under high temperature conditions.

Incomplete Design Planning for Orderly Growth to Maturity

A basic root cause of defectiveness in designs is incomplete planning of the overall design program. Initial design studies involve systems synthesis and analysis and include various extrapolations and projections. Numerous assumptions are made. Many decisions have to be made with a lower confidence factor than is desirable. Unless supporting tests are programmed to evaluate the validity of the assumptions and the decisions at the earliest possible time, major areas of defectiveness will go undetected until production is initiated. The complex of all tests on a large project is formidable. Consequently an integrated test program is needed during which an orderly growth of the product to maturity will be realized.

Dynamic Character of Design Requirements for Defect-free Methodology. The final report (AFSC-TR-65-6, January, 1965) of a study conducted by the Weapon System Effectiveness Industry Advisory Committee provides an insight into the dynamic character of design requirements for defect-free methodology insofar as the designer is concerned. In the introduction, the report says:

"The design and development of military systems has traditionally crowded the state of the art in materials, devices, and technology. In recent times, designers have been faced simultaneously with even more novel demands and acutely limited test data. Performance requirements invariably include severe reaction times which can only be met by closely integrating personnel,

procedures, and hardware. At the same time program cost limitations, accelerated development schedules, and lack of opportunity for complete systems tests prior to operational deployment have reduced the opportunity to obtain extensive operational usage data. Accordingly, what was once merely considered desirable is now considered mandatory—an integrated methodology of system management using all available data both to pinpoint problem areas and to provide a numerical estimate of system effectiveness during all phases of the system life-cycle."

Parts Requirements. A study related to the WSELAC report was conducted by an Ad Hoc group on Parts Specification Management for Reliability for the Office of the Director of Defense Research and Engineering and Office of the Assistant Secretary of Defense Supply and Logistics. The problem evaluated by the Ad Hoc group centered on the increasing complexity of military equipment and the need for improved specifications and quality control methodology to satisfy requirements on time and as economically as possible. Formally, the charge to the Ad Hoc group was:

"Increasingly more complex electronic equipments demanding high reliability have created the need for additional requirements in the parts and tubes specifications. The specifying of reliability in quantitative terms requires the introduction of reliability requirements into both equipment and component specifications, as well as the development of practical and economical test procedures to demonstrate compliance with the specifications. In addition, quality control procedures should include features to ensure maintenance of reliability levels throughout production runs."

Defectiveness Related to Production

Production conditions leading to defectiveness vary over a wide range depending upon the nature of the product. Initiation of production on military equipment may substantially overlap the development phase due to urgent defense requirements. This overlap is frequently accompanied by rapidly evolving changes in technology, as, for example, microminiaturization. Obviously, a considerable amount of defectiveness might be anticipated in the first equipment produced. Careful

advance planning to systematically correct defects will greatly reduce the overall impact and hasten the product growth to maturity.

Other products only change moderately from year to year, with many years leadtime planned for major changes in models. The automobile industry is a typical example of moderate changes from year to year. A major change, as for example, production of a gas turbine driven car, may have a development period of 15 years.

Notwithstanding the wide variation of products, a number of basic causes of defectiveness are common to many production programs.

Production Initiated Prior to Completion of Design Definitions.

Initiation of production prior to completion of the design phase, including qualification testing, would normally be considered only when conditions dictate a greatly compressed schedule. Rapid measurement and feedback of defects in the production process is extremely important with compressed schedules since the cost of correction will multiply rapidly so long as the condition producing the defect remains out of control and the production rate increases. As the number of design changes are apt to be great when production is initiated prior to completion of the design phase, configuration control becomes essential for proper evaluation of early test results. When test results are satisfactory, the successful configuration must be reproducible. On the other hand, when test results are poor, the configuration must be known so as to isolate the cause of failure.

New Processes Inadequately Qualified Prior to Production. In general, new manufacturing processes may be inadequately qualified prior to production because of incomplete planning or lack of understanding of their importance. In any event, the process cannot be considered to be completely qualified until a large number of production items, exercising the full range of possible parametric variations, have been produced.

Another example of inadequate planning is failure to conduct process capability studies. It is an obvious fallacy to commit the product to a

particular process when the analysis and calculations indicate the process is inherently inadequate to produce the required design characteristics.

Changes to the process will frequently result in unexpected defects unless each change is qualified in accordance with the initial qualification of the process as a whole. Documentation of the process change relative to date code or serial number of the production items affected is normally necessary for failure analysis. Latent defects found subsequently "downstream" in test must ultimately be related to the process configuration under which the defective items were produced so as to obtain corrective action.

Failure to Upgrade Shop Practices. Product defectiveness will increase exponentially if general shop practices are not upgraded with advanced product technology and the need for perfection. "Shop practices" means the various tangible and intangible ways of doing things that involve personnel, machines, management planning, instructions and communications. Shop practices that fail to keep abreast in the ever expanding technology and in the increasing need for improved workmanship are illustrated in the following examples.

- Failure to establish continuous training programs and training standards
- Failure to sense the general "esprit de corps," and provide meaningful motivation for excellence in workmanship
- Lack of recognition of tightened workmanship requirements from a technical standpoint
- Failure to provide improved working environments compatible with more rigorous workmanship standards
- Failure to challenge and correct slovenly work habits and housekeeping

Use

A surprisingly consistent causal pattern of defectiveness has been observed during the use phase of products of all types. This applies to use, operation, maintenance, and ownership by the customer. The basic pattern has striking similarity whether the product be a military weapon system, an industrial machine tool, or a consumer product. The pattern takes the following form:

- Inadequate communications, including data flow between producer and user
- Defective, incomplete, or inadequately prepared operating instructions/manuals
- Troublesome maintainability provisions and maintenance instructions
- Excessive downtime
- Spare parts not readily available

Communications

It is beyond the scope of this paper to fully explore all of the reasons for inadequate communications between the user and the producer. DOD and NASA have established a number of systems for providing data to the producer concerning product defectiveness found during military and space operations. In many cases, the data are very useful. Representatives of industry are repeatedly invited to participate in joint military-industry panels and other groups to improve communications. Substantial amounts of data are available for the asking.

For mass-produced items and services used extensively by the general public, data concerning public acceptance and product shortcomings is the very lifeline for generating knowledgeable marketing decisions. Decisions concerning new product lines, changes to products, and continuation of existing products is best based upon determination of reaction to defectiveness as defined by the public.

An interesting example is provided by the airlines industry. One of the major airlines had an aggressive quality control program for obtaining customer data concerning good points and bad points of the

airline's service to the public. Another major airline, lacking an effective data gathering program, was confronted with public distrust and loss of business. It went into an expensive advertising program to recover public favor. But more important, the airline modernized its customer practices to remedy its tarnished reputation.

Operating Maintenance Instructions/Manuals

Operating instructions and manuals are basically defective if they are not matched to the background, intelligence level, and training of the user. Instructions suitable to the Ph. D. graduate with 20 years' experience is absolutely worthless to a novice trainee. Additionally, defectiveness results from the multitude of problems arising from frequent changes in configuration that are not adequately documented. Sometimes a maintenance manual is not compatible with the equipment to be serviced due to changes in the equipment, errors, and failure to "qualify" the manual under actual maintenance actions conditions.

Defectiveness in operation and maintenance actions can be substantially reduced by human-factored analysis to simplify instructions. Clear, concise, uncluttered programmed instructions have been a major factor in the success of many products.

Maintainability Provisions; Spare Parts

Defectiveness in maintainability provisions and spare parts provisioning always reduces the value of the product to the end user. Poor maintainability provisions increase downtime and decrease availability. Low availability reduces the return on the investment from commercial and industrial equipment. For military equipment and many types of commercial equipment, curtailing availability below a predetermined threshold limit can have catastrophic results.

Summary

Technical causes of defectiveness are to be found in each of the major phases of the product cycle, i. e. design specification, design, production, and use. The impact of defectiveness tends to be most costly and difficult to correct when defectiveness permeates design specifications and design. Nevertheless, defectiveness in production and during use can also negate product value from the end user's standpoint.

Throughout this paper, the discussions on the technical causes of defectiveness imply or suggest various actions to minimize the root causes. However, the economics of such actions have not been elaborated upon. Actions involving changes in the way of doing things, or added initial costs usually have to be justified in terms of the benefit to be derived. It is often difficult to translate the benefits into absolute dollar values. Much can be done, and needs doing, by ingenious management to derive the cost elements of defectiveness and the dollar value of preventative measures.

PROBING AND ELIMINATING CAUSES OF DEFECTS

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When management recognizes that a defectiveness problem exists, it can establish a program for the discovery and elimination of the defect causes. The purpose of this paper is to show that the problems of defectiveness can be quite complex and requires the application of highly specialized skills, as well as effective managerial steps to eliminate their causes. In general, these steps include: organization to control defects, delineation of defects and defect causes, comprehensive review, and preventive measures.

Organization to Control Defects

Product defects can result from deficiencies in design specification, product design, manufacturing methods, manufacturing, packing and handling. The systems approach to defect elimination has, as its first essential, an individual or an organization having company responsibility for defect control.

The organization assigned this responsibility must have an understanding of the methods employed in all company activities. Knowledge of the defects which may be encountered and the techniques to be used in eliminating the causes of these defects is mandatory. Experience in product design, manufacturing methods, practical psychology, and the interaction between operating activities is required. While the defect control organization must have the support of management at all levels, it cannot depend upon this mandate for its acceptance but must make evident its sincerity and objectivity.

The organization having this overall defect-avoidance responsibility (called product assurance in some companies) ensures that the company consider such disciplines as reliability, maintainability, system safety engineering, human factors engineering, documentation, value engineering, and quality control. It will, on occasion, conduct reviews or audits to verify the operation of the defect prevention system.

Delineation of Defects and Defect Causes

A defect is usually thought of as an out-of-tolerance condition, a malfunction or even a blemish. The immediate cause of the defect may be faulty material, defective tools, operator error or any other manufacturing irregularity.

Manufacturing organizations usually deal with errors by making repairs and correcting the immediate defect causes. Only when the number of defects has an intolerable effect upon sales, production schedules, or profit is attention and effort directed to rectifying the basic defect causes.

To more clearly differentiate between these two conditions, immediate defect causes may be defined as those departures from material specifications, facility accuracy, and operator performance which result in defects. Basic defect causes are those departures from company procedures or good business practices which permit the development of immediate defect causes.

The following cases further illustrate the difference between immediate and basic defect causes.

Case 1. Normally, motor rotors are dynamically balanced before, but not after, impregnating them with an insulating varnish. The resulting motor vibration was intolerable.

Immediate defect cause: an improperly balanced rotor.

Basic defect causes: (a) the engineer who laid out the manufacturing operations did not know that the impregnation would unbalance the rotors; (b) most likely, both supervisors and workmen on the shop floor knew why the error occurred but no ready channel of communication existed between shop personnel and the process engineer to make possible a timely correction.

Case 2. An item of electronic equipment was plagued by a rash of intermittent short circuits. Investigations revealed that a design change had substituted nickel-plated screws with zinc-plated, high tensile strength steel screws. Further investigation disclosed that the factory, because of material shortages, had stripped off a portion of the nickel from stock screws, and then deposited a layer of zinc on the residual nickel. In assembly, zinc particles flaked off when the screws were put into their mating tapped holes. These zinc particles, deep inside the equipment, caused the intermittent shorts.

Immediate defect cause: zinc particles in the assembly.

Basic defect causes: (a) failure of the shop to follow approved manufacturing instructions which stipulated plating zinc directly on the steel screw; (b) the shop foreman had discussed the stripping and replating process with the plant chemist who advised against the rework because of the questionable bond between the nickel and zinc. The basic defect cause was the attitude of the shop foreman who yielded to production pressure and employed an unauthorized procedure. It is likely that this was not the first indication to management of the attitude of their first-line supervision. The basic cause may well have been management's condoning the lack of quality responsibility of its supervision.

The correction of defectiveness causes is usually not a particularly difficult task in industry, provided there is an incentive, such as defectiveness cost visibility. The correction of basic defect causes requires forceful administrative action and a greater expenditure of resources.

Comprehensive Review

An effective mechanism for the probing for defectiveness causes and their elimination is a survey conducted by a coordinated group under the guidance of the responsible product assurance organization.

Scope Determination and Survey Organization

Once defectiveness is observed, the extent of the survey will be determined largely by the company structure and the position the probing organization holds in it. The probe may include a survey of only one department such as purchasing, manufacturing, or engineering; but, since nearly all activities contribute in some way to defectiveness, the study is not limited to any one activity.

Once the objective nature of the study is made clear to the managers of the contributing activity, the sections are asked to provide people to represent their unit on the survey team. It is assumed that by being a part of the probe, the units will be more cooperative. Those assigned to the team should have a thorough knowledge of their organization's operating practices and an objective attitude toward defectiveness cause elimination.

Early in its survey operation, the team will review all available data concerning product defectiveness, even though it may be recognized that such data may be incomplete, biased, or include errors in interpretation. From the records of incoming inspection, process inspection, final inspection, test and customer complaints, the survey team may gain guidance for its initial direction and depth of penetration. The comprehensiveness of this phase is a direct function of time and budget allocated for the survey.

Review of Information Documentation

The survey team will have to become thoroughly familiar with all the written information the company provides to direct its personnel, including design, manufacturing, inspection testing, and packing instructions. Very likely, the study will begin with the design specification, and the team will pursue the following line of questioning:

Does the design specification reflect the customer's needs ?

Does the design documentation comply with the design specification ?

Do manufacturing instructions support design specification requirements ?

Do operator's written instructions comply with manufacturing instructions ?

Do inspection instructions enable the inspector to determine accurately how closely the product complies with the design documentation ?

Are the test procedures adequate to determine if the product operates and will continue to operate reliably within design specification requirements ?

Performance Study

Once these questions have been answered, there is still another set to be asked which pertain to compliance:

Has the design been qualified by suitable operational tests to demonstrate compliance with design specification in the environment in which the product can be expected to be used?

Have the production processes been qualified to assure that when they are conducted as delineated by the process instructions, the yield of parts produced in accordance with the design documentation requirements is acceptable?

Are individual operators properly instructed and have they demonstrated proficiency in performing in accordance with manufacturing instructions?

Are inspectors suitably instructed so that they will accept only those materials which are in accordance with design documentation?

Are test personnel adequately trained to assure that they perform the test in accordance with the test procedure, and based on the test, make appropriate disposition of the tested material?

Has the test equipment been suitably calibrated to assure that when operated in accordance with the test procedure it will accept only that material which performs or supports performance in accordance with the design specification?

These are only examples of the most important areas to be questioned. The review will be much more detailed and it will continue into the examination of the instruction of supervisors, material handlers, material packers, shipping clerks, tool designers, tool makers, etc.

Under some stringent quality assurance systems, the performance of certain key operations is trusted only to specially certified operators. These operators have received special training in specific operations and have demonstrated, over a significant time period, their ability to perform these operations efficiently. Operator certification is mandatory by NASA, Quality Program Provisions for Space System Contractors, and Quality Requirements for Hand Soldering of Electrical Connections.

The survey team's next step is made with the managers of the activities involved in the product under study. Each manager is advised that in the event defectiveness-cause elimination action is required in his operation, he will be the first to be informed. The details of the team's findings and its conversations with the manager will not be discussed elsewhere until the manager has had time to effect remedial action. Unless the manager is convinced that the activities of the team will not reflect adversely on his performance, the team cannot expect the manager's full cooperation.

Later in the survey program, after becoming more familiar with the actual product quality and the shop operations, the survey team may wish to discuss the defectiveness problem with the supervisors and engineers who are most directly concerned with the product. These people live with the problems of design, manufacture, and defectiveness, and they usually have revealing clues to the sources of defects. Still later, the team may wish to discuss the defectiveness problem with individual operators, inspectors, and testers. Not only are these people frequently able to make significant contributions to the survey, but they are also pleased to contribute to defectiveness-cause removal.

At the shop level, the survey team has another set of questions to probe all manufacturing operations, processes, practices, inspections, and tests:

What is the function of this operation?

Does this operation presently accomplish this function?

What evidence do we have that the operation will continue to accomplish this function under all conditions of material variation, facility maintenance, and operator proficiency likely to be encountered?

Are the requirements for the material, facility, operator skill level, and other parameters appropriate for the function to be accomplished?

Is there an alternate method which will accomplish this function with greater accuracy and with equal or better overall economy?

Is the shop operation method fully documented for the benefit of the operator ?

Does the operator have a means of knowing when he is performing the operation incorrectly ?

Does the operator know how to make changes in his operation when he has an indication that his work does not comply with requirements, and does he know when to stop and ask for assistance ?

Evaluation of Findings

Still other questions must be posed by the survey team to get an analytical understanding of the problem:

Do purchase orders and contracts with subcontractors include clear statements of all essential requirements ?

Is there an adequate program for tool inspection and tool-made sample review ?

Is appropriate action taken on the points raised as a result of the tool-made sample review ?

Is there an adequate program for first-article review ?

Is appropriate action taken on the points raised as a result of the first-article review ?

Are operators adequately instructed ?

Are the manufacturing instructions sufficiently detailed ?

Are all essential inspections being conducted ?

Are all essential tests being conducted ?

Are appropriate decisions being made as a result of the inspections and tests ?

Are appropriate decisions being made on nonconforming material ?

Is there an active program for the determination of defect causes ?

Are these remedial measures being instituted promptly ?

Is there a system whereby the total cost of defectiveness is regularly brought to the attention of the plant management ?

Follow-up

The survey team should conduct a follow-up survey six or eight weeks after submitting its findings to assure that appropriate changes have been initiated. If the corrective measures have not been taken, the supervisors of those responsible for making the changes should be notified. It is essential that the survey team assure that the basic, as well as the immediate, causes of the defectiveness are corrected.

For the follow-up and for the purpose of perpetuating this control, many manufacturers have established a permanent organization to eliminate the necessity for repeated reviews of the same immediate and basic defect causes.

Preventative Measures

Management at its various levels has the responsibility of guiding the application of the available specialized techniques to the most fruitful areas for the removal of basic defect causes. The organizations having the responsibility for these activities are not always in a position to optimize the full scope of application of their technologies.

Industrial Methods

Industrial engineering has as a prime objective the reduction of manufacturing costs through the development and selection of suitable methods. When defect prevention is also a consideration in the method selection, further cost reduction can be achieved through reduced rework, retest, and scrap. Manufacturing methods can be designed to render defect creation improbable, if not impossible, or can provide for prompt and automatic detection. Frequently, these defect avoidance methods will not increase operating costs.

Other adroitly utilized industrial techniques, a few of which are discussed below, can contribute to defect prevention. The success of the technique will be enhanced if some participation in their development is permitted the supervisor and, in some cases, the operator of the performing operation.

Uniformity of processing methods will contribute to defect reduction. However, progress must not be discouraged; before a new method is adopted, it must demonstrate that it will accomplish consistently the operation's objectives.

Industrial engineers recognize that operators will work more accurately if they are permitted to develop natural, uniform patterns; defects can be expected when out-of-pattern work is attempted. Through motion study and work simplification, both of which are best accomplished when the operator participates, these engineers can select the one method that will yield the greatest number of defect-free units.

The industrial engineer can determine the types and degrees of contamination most detrimental to product quality and provide suitable controls for specific contaminants. Since every individual can contribute to contamination, each can contribute to its control.

Through the use of computers, engineers can analyze inspection and test data to determine the most promising areas for remedial action. Computer techniques can be employed to control configuration, to test equipment calibration, for qualification tests, and for a host of other tasks essential to the reduction of defect causes. Once it is demonstrated that computer outputs constitute feedback information contributing to the program's success, the individual can more willingly incorporate changes in his work pattern to improve his performance. Such changes, naturally, must be consistent with the approved processing method.

Physiological and Psychological Considerations

Inability to perform in the prevailing environment for physiological or psychological reasons can constitute a basic cause of defects. Medical specialists can assist in the selection of personnel and in establishing standards for light, temperature, humidity, and noise levels most conducive to high quality performance in specific occupations and processes. Where certain processes make extraordinary demands upon the visual and auditory acuity of personnel, physicians can recommend aids to improve performance and reduce fatigue.

In certain operations, production operators can induce defects simply by their proximity to the product. Some materials are sensitive to contamination by dandruff, cosmetics, flaking skin, and acidic perspiration. Even the electrical charge built up on the operator's body because of synthetic materials in his clothing can damage certain products.

Quality Assurance

Quality assurance is concerned chiefly with compliance of products and processes to contractual requirements. The QA plan is usually formed well in advance of production activity. It is coordinated with the plans for production, processes, facilities, and materials so that all factors will support compliance with requirements. Quality assurance will maintain a surveillance or, in some cases, perform inspection and tests in various stages up to and including installation of the product at the customer's facility. Such inspection and tests are structured to verify conformance to specifications and thus prevent unsatisfactory operation of the product in the customer's hands.

Quality assurance employs statistical data to isolate defect causes. The relationship of the data to established control limits indicates when an investigation to determine assignable causes of defects is appropriate. Astute analysis of the data will usually uncover immediate defect causes and lead to basic causes.

Statistical Methods

The statistical methods commonly employed by quality assurance may be used also by design and manufacturing engineering to isolate defect causes. Statistical sampling, results charting, and the establishment of control limits are common quality assurance applications. In the field of design engineering and failure analysis, statistics can be employed in the design of experiments. Through the study of test data distributions, engineers can make design refinements and reduce defects. In many areas, statistical data fed back to individuals will encourage them to adopt improved practices.

Company-operated suggestion systems, whereby the individual is given financial remuneration for contributing a usable design or process change, have been augmented by systems which grant awards for identifying error causes, whether the details of the change are suggested or not. Effective through these systems are when properly administered, even greater cooperation by the individual can be expected if he is encouraged to offer informal suggestions and is permitted to participate in methods development.

Error Cause Removal

The prodigious complexity of some modern systems has led the technical world to a better appreciation of the magnitude of the design debugging task. Each new set of defect causes encourages specialists to develop controlling disciplines to assist the designer. Activities such as nondestructive testing, failure analysis, system safety, and physics of failure make important contributions to fault avoidance. Engineers schedule design reviews with teams of specialists. Computers assist the designer in exploring a range of conceivable designs. Communication systems have been expanded to enable one engineer to profit from the experience of others.

The complex problem of defect avoidance is nearly impossible for chemists, physicists, and engineers to solve completely in an allotted time. After using the best of the multitude of defect avoidance techniques, these creative people must eventually pass their designs and processing instructions to the manufacturing engineer and manufacturing personnel. Once this second group of people are made part of the defect avoidance team, other ways will be found to further improve the product quality.

Motivation

The individual's psychological orientation to his assignment will affect his skill. Management is responsible for influencing that psychological orientation. Experience has shown that skillfully structured motivational programs can contribute to defect elimination, cost reduction, and morale improvement. Motivation is a branch of psychology, and, like all specialties, it is wise to enlist the services of a

competent professional to help create a formal motivational program. However, all supervisors and managers must employ motivational methods in some form, and it is essential that these people be given appropriate training.

The supervisor must maintain an open channel of communication with the individual. He must listen to each of his people and then act in such a way that the individual is confident that he has his supervisor's support.

When two-way communication is established wherein the employee is given an opportunity to express his own suggestions, he will have a feeling of participation, provided, of course, that management demonstrates sincerity by taking some action as a result of his contributions. All information concerning the management of the company, whether directed to the employee or not, will have its impression upon the employee. However, because he has more opportunities to talk directly to the employee, the first-line supervisor is in the best position to contribute most to the employee's knowledge and impression of the company.

Every company has finite goals. Psychologists recognize that each individual has his own personal goals and that the individual will be constructively motivated if he is shown that he can achieve his own goals by contributing to the achievement of the company's goals.

If employees can identify themselves readily with the company or with a unit of the company, they will have a feeling of personal involvement and will feel responsible for their work as well as for the work of the unit as a whole. Some companies stimulate esprit de corps by forming groups which compete in cost performance, schedule performance, suggestions, and work accuracy. Unless judiciously handled, such programs can have serious long-term negative consequences while achieving short-term goals.

Feedback

In spite of efforts to account for all factors influencing performance and reliability goals, not all the variables are under the full control of the designers and planners. Problems and reverses cannot always be anticipated somewhere downstream. Defects and failures do occur. Information feedback can be the means for lessening their impact by increasing the knowledge of all who participate in creating the product.

The way is not easy. It requires the collection and analysis of data, the determination of the assignability of cause and the transmission of data to the individual who can use it best to modify the causative system. Serious failures of major systems receive extensive attention and the producer of the offending component is alerted. Many less spectacular failures also deserve careful analysis, since in these failure causes there may be more important latent defects.

The principle of feedback does not belong in the province of product defects and performance failure alone; it applies to all industrial activities. Thus, the operator should be informed of his previous errors and his current level of accuracy. Responsible designers should be advised of the suitability of their designs following design reviews and qualification testing. Management should be informed of the true worth of the employee-management communication channel and the effectiveness of their motivational techniques. Appropriate corrective measures must be initiated, whereupon the effect of these corrective measures can again be analyzed and reported.

Summary

Responsible industrial management operates under the precept that product defects result from a system of defect causes including both the immediate or direct causes and the basic or indirect causes. In the main, the elimination of defects is accomplished by the control of these defect causes. These are the essential steps:

1. Establish an independent activity with appropriate skills and authority to prevent development of the defect causes
2. Establish a defect avoidance program and recruit the participation of all activities which contribute to product quality
3. Establish a mechanism for determination and elimination of both immediate and basic defect causes
4. Provide for suitable motivation of all personnel whose work can have an effect upon product quality
5. Establish a feedback mechanism which will give a reliable indication of both the true product quality and the effectiveness of the defect avoidance program

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ASSESSMENT OF PROBLEMS AND OPPORTUNITIES

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Any management technique is effective if its use has been properly planned in consonance with its limitations. Zero Defects is such a management technique. It can create additional sources of cost savings and profit when used intelligently. However, it is not a magic formula that will make defects disappear, nor is it a publicity attention-getter without real merit. The Zero Defects technique must be directed toward goals that will be most beneficial to the organization.

This paper will examine the manner in which a company or organization can make a factual assessment of the opportunities for Zero Defects philosophy and techniques. It will explore two fundamental areas of activity:

- Actual manufacture of the product
- Software, i. e., paperwork and paper systems involved in the support of hardware production, or a product unto itself

Further, this paper will assess those areas promising the most return, illustrate a technique for selection, and give specific examples of program accomplishment.

General Application

Management's decision to undertake a Zero Defects program must be based on a thorough evaluation of objectives. It is possible to have a Zero Defects program whose sole objective is to achieve intangible and unmeasured improvement by motivating personnel to try to do a better job every day. To the degree that the motivation program is well planned and organized, some beneficial results will accrue, even though progress cannot be measured in tangible terms. The benefits of the motivational approach, however, can hardly be compared to those possible under a complete, properly planned, well organized program. As the name

implies, a Zero Defects program should tend toward elimination of defects and their source. Only by the most careful planning and organization can identifiable improvements be achieved.

Selection of the various elements of the program and clear definition of realizable goals are the foundation on which a successful program can be constructed. The assumption that an idea, if it has merit, can be applied universally and indiscriminately with equally beneficial results is a common fallacy. The Zero Defects philosophy has sometimes been subject to such indiscriminate application. When the results have turned out to be less than satisfactory, the philosophy of motivation has been blamed rather than the lack of proper planning. Therefore, management's first acts should be to examine existing problem areas, identify known defectives, and build the plan around these knowns.

A Zero Defects Operating Committee, with representatives from all or most of the participating organizational units, develops objectives for the program. Plans for meeting these goals should be imaginative and free from the constraints ordinarily imposed on motivational programs. Unfortunately, many defectives, problems, and sources of error never get exposure during the normal course of events. Every element of the organization, then, should be explored for identifiable and measurable errors. Experience shows that many areas have made extraordinary improvements in the first few months of a Zero Defects program simply because unobvious errors and their sources have been uncovered and their reduction measured.

Areas of Opportunity

The most obvious target of a Zero Defects program is manufacturing, where a reduction in scrap or rework costs will result in direct dollar savings. Less obvious, but equally fruitful, is its use in functions not normally measured by production standards but where increased efficiency and effectiveness can make a measurable improvement in cost. The somewhat neglected area of software functions, such as accounting, paperwork, billings, and key punch operations, are particularly suited to a properly organized Zero Defects approach and analysis. Any function that has details of its work readily available for examination can be considered susceptible.

The normal functions of an organization can be generalized in two categories: hardware-oriented and software.

Hardware-Oriented

Manufacturing
Test operations
Tooling
Quality control
Supplier hardware
Production control

Software

Financial administration
Engineering
Industrial relations
Logistic support
Contract administration
General administration

The paragraphs to follow outline some areas for improvement which have been used in successful Zero Defects programs. They do not in any sense identify all of the opportunities present for exploitation. Each company, each organization, has certain functions that may receive special emphasis by the planning committee. Therefore, part of the planning for a successful program must be a thorough review of all functions for potential areas of improvement.

Manufacturing

Manufacturing progress is easier to identify because reduction (or increase) in defects are chartable without developing new parameters. The problem is in choosing representative targets from those that exist, not in creating the measurement.

Measurement of quality such as defect-rate-per-thousand-hours-of-direct labor, scrap dollars, defectives-per-unit or percent-defective is appropriate. Proper selection of the group or area to be charted so that a healthy competition is created is really more important in many cases than the measurement itself.

Although measurement of quality parameters or defectives are desirable, the planning group must not overlook the substantial benefits to be realized by posting other standards of manufacturing performance, e.g., reduction of labor hours per unit, idle time per department, and paperwork errors in production work sheets. These and similar work parameters all have an effect on the organization's overall performance. Further, improvements are usually obtained quickly under the proper motivation and competition.

Executive personnel should be cautioned that it would be unwise to expect every element to show a tangible dollar savings or improvement. In many cases, the improvement in employee morale and enthusiasm will develop intangible savings through better work—savings that can never be evaluated in bookkeeping dollars.

Test Operations

Testing, particularly acceptance testing, is fundamentally an extension of the manufacturing cycle and is subject to many of the same controls and measurements. Retest time due to operator error, test procedure error, or machine breakdown are excellent Zero Defect indicators.

A good measurement of the test planning function can be the number of errors-per-page of planning. Similarly, the number of procedure revisions due to incorrect analysis of the basic specification requirements indicates basic competence of the test planning personnel. The number of discrepancies discovered as a result of test preparation and hookup also can serve as a stimulus for improved performance.

Tooling

Tooling includes both hard tooling for structures and electronic tooling for the fabrication and test of components. Tool rejections in either category constitute an easily recognizable added cost, readily susceptible to motivation techniques.

Timely completion of calibration cycles, reduction of standard rework hours, and turnaround time for production line tools are also excellent performance measurements.

Quality Control

A most effective measure of the quality organization performance is product conformance to specification as seen through the eyes of the customer. Similarly, the effectiveness of any part of the inspection task can be gaged by the frequency of discrepancies appearing later in the production cycle, e.g.:

- Total number of discrepancies-per-unit found by the customer after final company acceptance

- Paperwork discrepancies found by the customer at time of delivery
- Defects discovered at a subsequent inspection that should have been detected earlier (expressed as either total discrepancies-per-period, or defects-per-unit)
- Procured material rejected after inspection
- Time required to conduct failure analysis of defective parts and to produce a report

Supplier Hardware

Achievement of Zero Defects in supplier hardware requires a superior quality of performance within the procurement organization as well as within the supplier's house. The buyer must adequately define supplier requirements, evaluate his capability, and review and report his performance without error. Some measurements that have been used as goals in these areas are: rejection rates on supplied hardware as a result of supplier discrepancies; rejections of hardware due to improper handling and/or packaging by either the supplier or the buyer; errors detected in purchase requisitions originated or approved by buyer personnel; rejections of subcontracts or contract termination documents by the customer; latent defects discovered after receiving inspection and incorrect data furnished by the supplier.

Production Control

In ordering material, maintaining stock rooms, and issuing material for work in the factory operations, production control can be easily integrated into the Zero Defects program. Some measurements relating to the functions of this organization might be: the number of discrepancies noted against packaging of components; quality rejections relating to storage of age-sensitive or environmentally-controlled hardware; shop-detected errors in part ordering and supply; issuance of jobs to the manufacturing organization with incomplete information or instructions. These, and similar-type measurements, reflect errors which are directly relatable

to increased costs from idle time or rework. The reduction of errors results in direct and immediate savings.

Financial Administration

The financial operation offers some excellent opportunities for motivation techniques and scoring. Rapid handling of billings to take advantage of discounts can be scored as dollars saved. Incorrect payment as a result of accounting employee error, incorrect payroll checks, and errors in petty-cash disbursements are also subjects for measurement.

In organizations with customers who regularly review requests for payment or projections of future billings, accuracy of the accounting method can be improved by making the customer's analysis of the operation the basis for an improvement goal.

Engineering

Product quality must begin with sound design. Not only is this a proper concept, but it is also the criteria and definition for establishing controls to ensure a consistent and desirable level of quality, as illustrated in the following measurements of design group output that have been used to stimulate and motivate engineering personnel:

- Design changes required after initial release as a result of engineering error, expressed as either number-of-changes-per-period or percent of all changes due to error
- Drawing-errors-per-page found by the engineering checking function
- Percent of documentation rejected by the customer
- Percent of drawings not suitable for reproduction because of legibility or format errors
- Actual engineering design time versus projected budget time

Industrial Relations

Although industrial relations is intimately concerned with people motivation, setting Zero Defect goals and measurement standards for that function has often been met with resistance and actual disbelief.

Actually, a number of industrial relations functions are readily adaptable to the program. Improvement in the time for processing employee classification changes, reduction of errors in transmitting TWX messages, and more rapid mail service are examples of elements that can be measured.

Where the reproduction of drawings, specifications, documents, etc. is often a function of this department, a number of other measurements are available: percent of rerun for illegibility; inaccurate count or collation; rerun time for incorrect number and returns from customers.

Logistics Support

The quality of production operation and maintenance depends, in large part, on the support provided the user through technical information, spare parts availability, and adequate special tools for maintenance. The quality of these efforts can be identified and measured by such statistics as:

- Rejections of technical manuals by the customer for erroneous or inadequate information
- Percent of spare parts availability against a requirement
- Number of times maintenance equipment fails to perform
- Errors-per-page of technical writing discovered by checkers or by the user
- Overall measure of direct man-hours-per-page of technical writing on a time basis

Contract Administration

Today's business climate requires a myriad of contractual agreements and products specifications. These documents are submitted to numerous reviews within the organization and by the customer. Each review

furnishes quality performance data on the correct wording of requirements, spelling and typographical errors, proper criteria and tolerances, and contractual intent. An additional measure of effectiveness is the comparison of the timely submittal of data against the official contract dates.

General Administration

Although the functions assigned to the administration department may vary considerably from company to company, the activity generally covers a wide variety of paperwork activity such as procedures, business machine control, and certain aspects of planning. Rarely has the effectiveness of such activities been exposed in the past, but their inclusion in motivation programs have produced excellent results.

The functions of computer programming and operation are particularly suited to Zero Defect type goals. Rerun time of computers for machine or personnel error, key punch errors as a percent of total cards handled, total elapsed time from information request to delivery to user are all readily measurable, and improved effectiveness is reflected in immediate dollar savings.

Production of organization procedures can also have meaningful measurements such as errors-per-page of reproduced copy; average number of drafts per completed and approved procedure; and number of required revisions after issuance.

Method of Assessment

As indicated earlier, the Zero Defects Operating Committee has the basic responsibility for developing program objectives. Such a group can make the best assessment of the suggested goals developed by the organizational units, and can also offer ideas which cross departmental lines. Some of the best goals frequently come from outside the function to be measured.

The initial step in the assessment loop is to develop a list of the work elements or functions of each segment of the operation. The depth and formalization of this identification is, of course, dependent on both

the size of the organization and the amount of money budgeted for the program. Many of the elements are so basic and well known that listing them seems almost unnecessary, but all must be itemized.

As an illustration of the process, consider the case of a welding department in manufacturing. An oversimplified listing of work elements would include: (1) hand welding, (2) machine welding, and (3) automatic machine welding. A further breakdown of the automatic machine welding operation lists:

Material preparation

Time

Degree of cleanliness

Setup time

Run time

Defects

Total number

Inches of defect versus total inches of weld

Defect repair

Inches of repair versus total weld

Cost of repair in dollars

Cost of repair as percent of basic product cost

Rework time as percent of product run time

Total lost time per period (month, week) due to rework

Analysis of these individual operations determines which are worthy of inclusion in the program. Quickly eliminated are those of small value or those not readily measurable.

Although the illustration proceeds in a formalized manner, many of the most important goals are quickly selected on the basis of obvious merit. Further, Zero Defects achieves improved quality and reduced cost through the motivation of individuals and groups. The selection of goals for public display must be chosen with regard to their appeal to the individual, and to their stimulation of group competition.

Returning to the example of the automatic machine welding, it is apparent that significant improvement items are identifiable. To reduce the number to a smaller group to ensure proper emphasis, the working committee must analyze them all. Table 1 lists the results of such an analysis and indicates which of the elements are to be included in the program.

The same type of analysis can be applied to a function whose output is largely paper. In looking at the opportunities for increased effectiveness in general administration, the possibility of defect prevention in computer and business machine use can be examined. In an organization using computers, the basic elements can be identified as:

- Data control—input preparation (basic data transmission)

- Key punch

- Data control—verification of card data

- Machine operations

- Card-to-tape

- Computer programming

- Tape to printout

- Data control—verification of printout

- Rerun due to errors

- Delivery of information to user

Table 2 shows the analytical breakdown with respect to program importance. The possibility of measurements in this area are so numerous that only the most meaningful can be included. The conclusion that errors requiring a computer program to be rerun are very costly and must be closely monitored is quickly reached. Elimination of operator errors which result in several hours of rerun time at hundreds of dollars an hour is a cost return understandable at all levels of management.

The technique illustrated by the two preceding examples can be applied to any part of any organizational function. Complete application of such a formalized approach may not be required in many instances, but it offers a method that will ensure selection of meaningful goals.

Table 1. Project XXX: Welding Department—Automatic Welding

<u>Item</u>	<u>Significance</u>		<u>Include</u>	
	Yes	No	Yes	No
Material preparation time				X
Material cleanliness				X
Setup time			X*	X
Run time				X
Defects				
Stable operations—small dollar significance				
Not readily susceptible to measurement				
High dollar value—variations could be significant				
Does not vary of itself				
Total number			X*	X
Inches of defect versus total inches of weld				
Defect repair			X	
Inches of repair versus total inches of weld			X	
Repair cost in dollars			X*	X
Repair cost versus basic cost			X	
Rework time as a percent of total run time				
Total lost time per month due to rework			X*	X
Excellent quality indicator—has good employee understanding			X	
Good cost indicator			X*	
A better overall cost indicator			X	
A good all-around indicator				
Good all-around indicator—useful on a month-to-month basis			X*	X
			X	

*These measurements were eliminated after further consideration; the four remaining were included in the program.

Table 2. Project XXX: Computer Section

<u>Item</u>	<u>Significance</u>	<u>Include</u>	
		Yes	No
Input preparation	Not of major significance--difficult to identify		X
Key punch	Can be time measured--error rate (rerun time) is a better indicator		X
Verification of cards	Relatively standard time problem--key punch error rate/operator an excellent quality indicator	X	
Machine operations	Function of time--mechanical breakdown can affect cost. Not a frequent occurrence.		X
Verification	Timing standard--error. discovered a better indicator (see rerun listing)		X
Rerun time			
Machine failure			
Disc	All machine failures are excellent indicators of machine capability. They do not serve as good motivation goals because they do not respond to direct employee activity.		X
Drum			
Reel			
Human failure			
Control desk	All errors in this category are excellent indicators of employee performance and also represent realizable cost savings with improvement, and offer excellent opportunity for both individual and group competition relative to improvement.	X	
Key punch		X	
EAM operator		X	
EDP operator		X	
Management system		X	
Delivery of information	Not significant		X

It further ensures management exposure to possible problem areas that were not previously recognized or identified as important.

Examples of Accomplishment

When setting out on a Zero Defects program, it is important to understand that the program will produce results. It is useful, also, to have some definitive knowledge of what has been accomplished by other companies. The charts on the following pages are actual results obtained during the Zero Defect programs of several large organizations. They represent the type of measurable improvement that can be obtained with a well-organized, well-managed program.

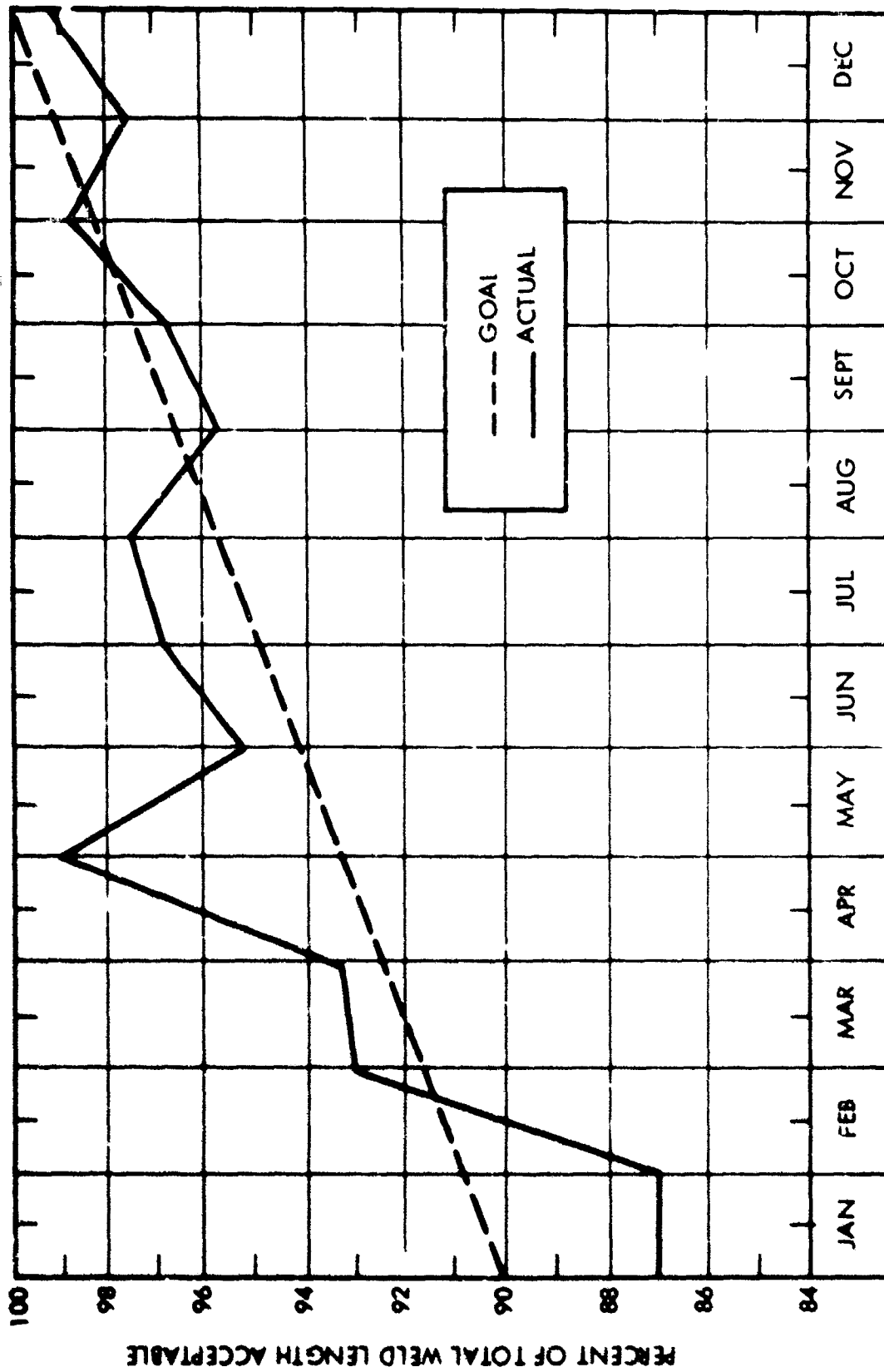
Summary

Zero Defects is a management technique that has both widespread appeal and universal application. It serves as a motivational device to encourage people to do better work and, at the same time, provides management with clear indicators of reduced defectives or, conversely increased effectiveness.

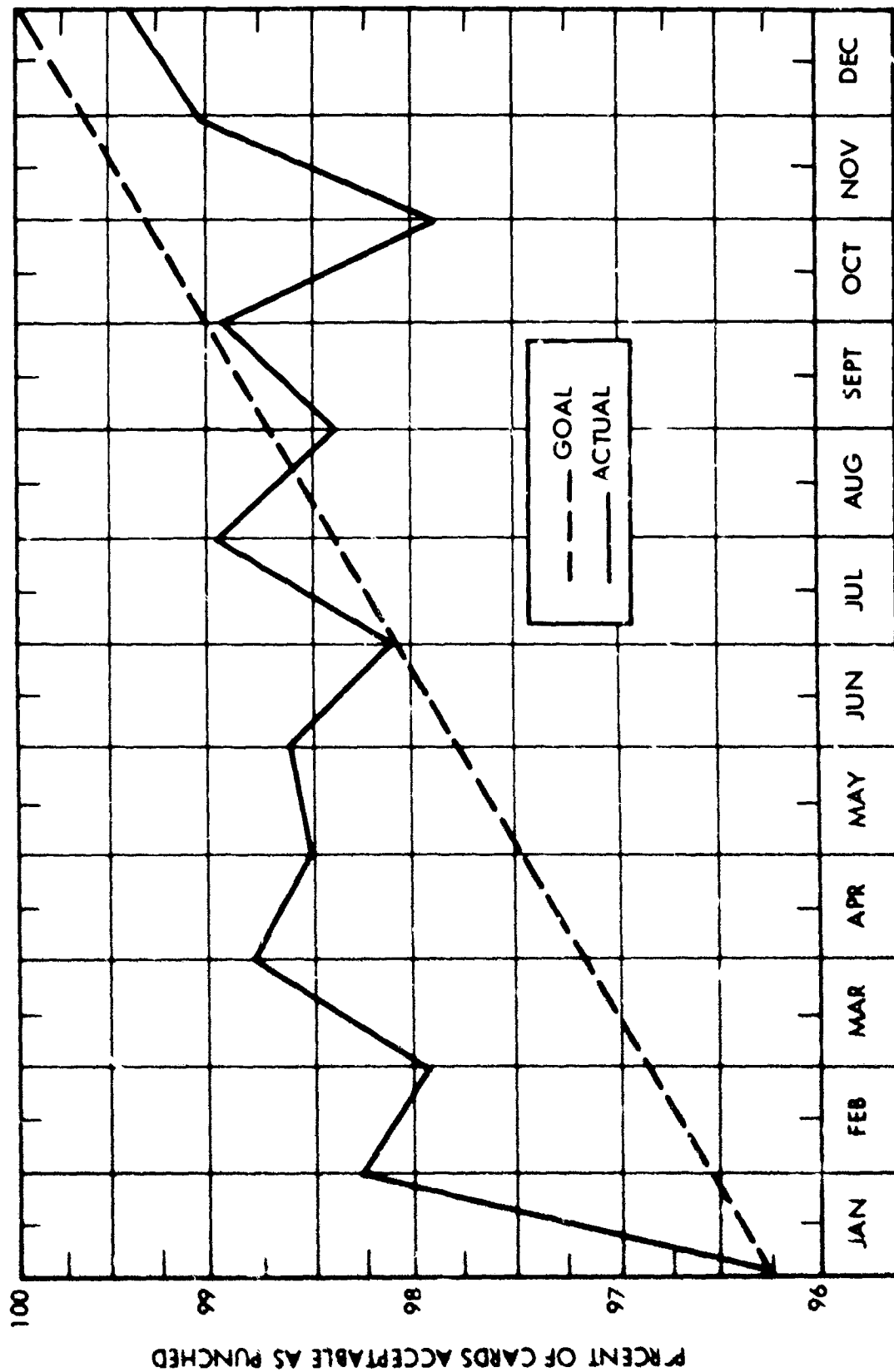
The opportunities for its application range from assessing the performance of hardware production to handling and distribution of paperwork. Although any function where improved performance would result in cost savings is a good candidate for the program, the fundamental goal of Zero Defects is to achieve results by motivating people to do better work; any effort of this type must have a basic appeal to the employee.

Goals are selected only by thorough analysis of the numerous possibilities, and a formalized listing of the various opportunities is often desirable. A few well-chosen, properly identified and enthusiastically supported objectives will bring greater returns than numerous goals selected at random.

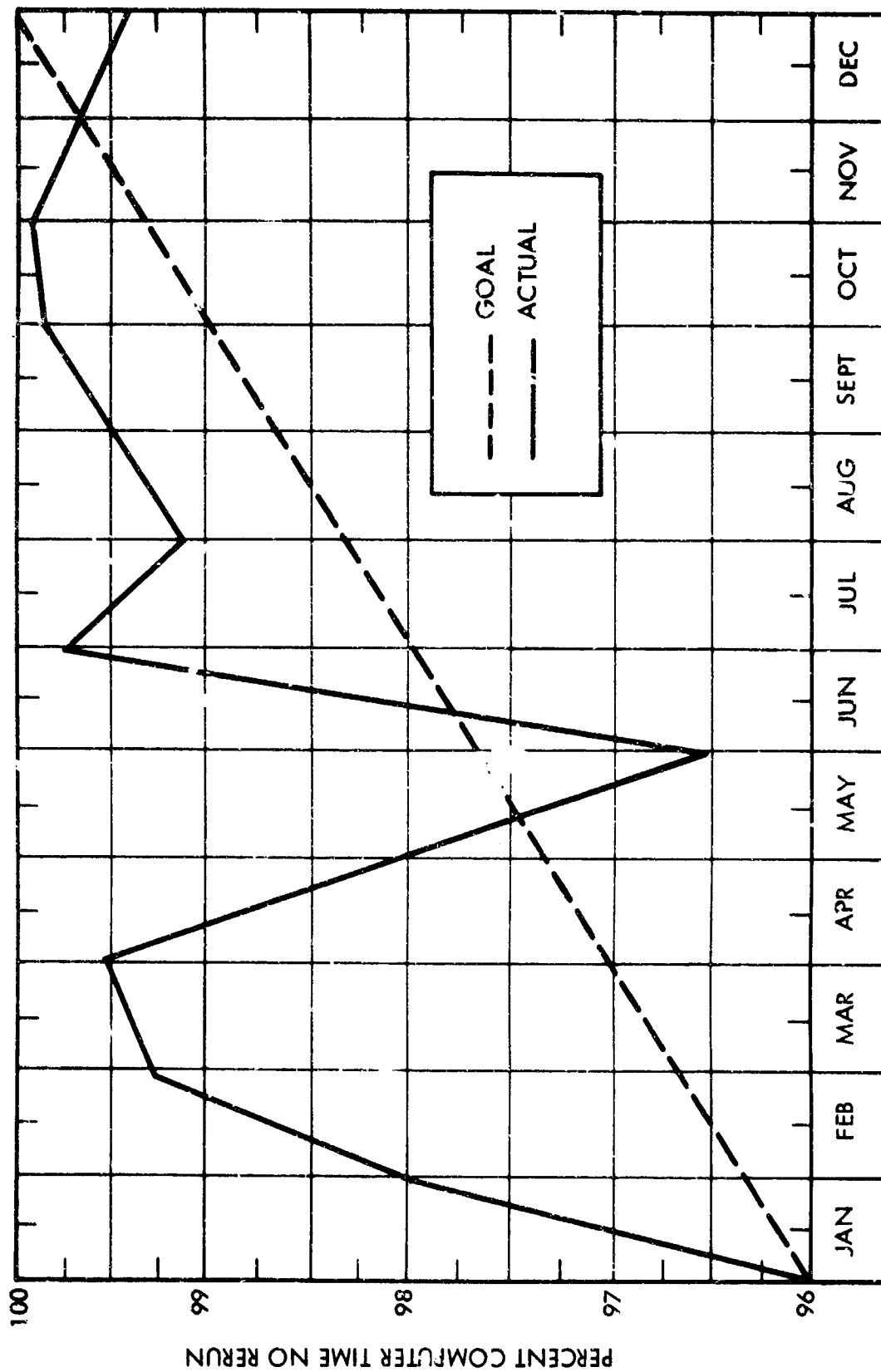
A properly organized program can bring positive benefits in fewer defectives, reduced cost, and increased employee enthusiasm and interest in the basic objectives of the organization. A bonus from the effort is an improvement in the company's competitive posture, a most important element of all business operations whether it be government, manufacturing, or commerce.



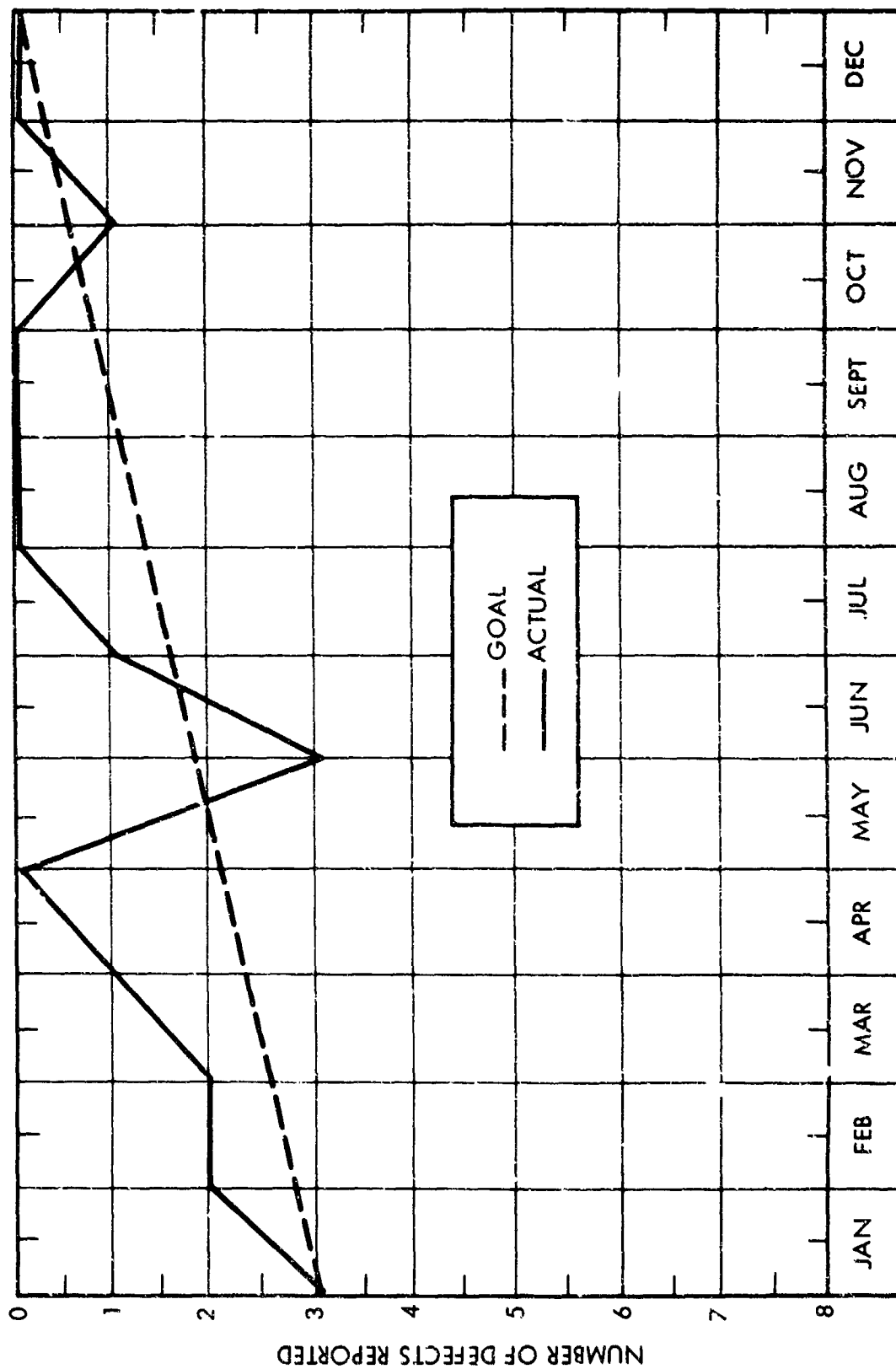
Inspection Acceptance of Welds — Tank Dome Assemblies



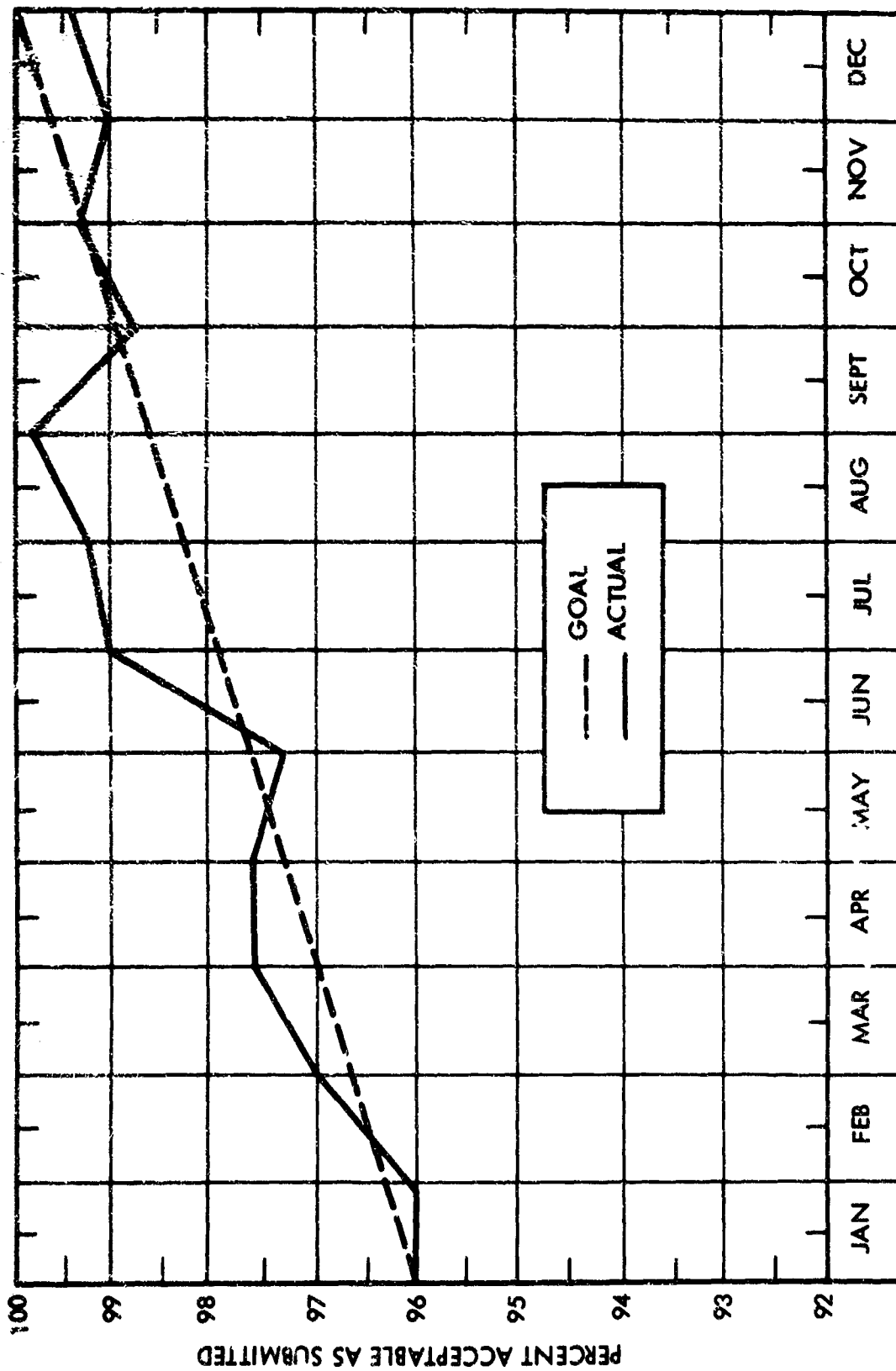
Key Punch Operation — Reduction of Cards Requiring Replacement
due to Operator Error



7074 Computer Operations—Reruns due to Operator Error



Electronic Equipment Defects Reported after Delivery



Engineering Jobs Acceptable for Reproduction

ASSESSING PROGRAM EFFECTIVENESS

A. R. Tocco, Director of Value Assurance
TRW Systems Group

People everywhere are meeting the challenge of Zero Defects every day. But the extent of their success cannot be known without performance measurement; and to be applied with any insight or accuracy, the elements of a viable ZD effort must first be examined—description must properly precede assessment, as there is no evaluating the undefined. Obviously specific company programs will derive their focus from that organization's products, services, and particular needs; nevertheless, certain basic principles are common to all good programs, so they serve as ready-made checkpoints for assessing other programs. Therefore, we propose to survey these fundamentals from the appraisal standpoint—the resulting guideline provides a working frame of reference for determining the effectiveness of any industrial ZD operation.

Directing the Program Toward the Goal

Ideally, the goal of a zero defects program is the attainment of perfection. Although the management policies underlying this goal, of necessity, should be firm, the path to it must be flexible, challenging, and realistic. Further, the implementation of that policy must give due consideration to the human element, since people make the program work—not vice versa.

Program objectives, therefore, should be of interest throughout an organization. However, the relative assessment of attainment varies with level. Top management looks for higher quality, lower costs, larger profits, and an enhanced corporate image. Other employees may view the results in terms of personal pride and incentive, competition, recognition, and responsibility. Whatever the view, the assessment of ZD program effectiveness must be made and presented in a manner understandable to all levels. Moreover, that measurement must be presented so as to stimulate continued adherence to meeting the objectives and not result in demotivating already "fired-up" supporters. At this stage, performance

improvement is the first consideration. Therefore performance-oriented activities are important; time-consuming tangents are not—they merely disguise problems and delay solutions. With poor timing or misdirection at the outset, the most inspired ZD effort can waste effort, and thereby diminish its own impact or defeat itself entirely.

The characteristics of initial interest in ZD sometimes provide clues to future participation. Therefore, it is wise to check the program's early progress for possible signs of misdirection, misinterpretation, too much motion, too little action. Program acceptance precedes program effectiveness, and people must understand before they accept. Random questioning of those directly concerned—instead of formal reports—is usually more revealing at this stage: What does the average employee know about the program? How does he feel about it? What trouble should be averted or corrected?

Employee Commitment

Total commitment of employees is, of course, the optimum, but it must be voluntary. Management may pose the goal or challenge to excellence; employees will accept it only if they want to accept it. And they will accept if the program emphasizes areas of proven interest to them—their job security, procedures, techniques and facilities. Further, experience proves that employee support is closely linked with employee involvement. The greater the employee participation in the goal-setting process, the more total his commitment to the program.

From this standpoint, employees can view ZD in terms of participation in management: each man's chance to help direct the affairs affecting him and his work situation. Once realized, this kind of cooperation puts a fair exchange to work for the program: the employee gives his support, and gets a decisive managerial voice in return.

A true sense of involvement leads further to employee initiative, which in turn breeds industrial phenomena like Japan's renowned "QC Circles," wherein work leaders and line operators voluntarily undertake analysis and solution of job problems on their own time. Circle membership is limited to people from the lower rungs of the organizational ladder,

on the assumption that no one is better able to identify and correct the problems encountered on the job. Results? Some groups have inaugurated major quality breakthroughs. Practically all have significantly lowered assembly defect rates. The QC movement is now a nation-wide marvel—a world-wide model—and a striking example of the lengths to which participation can take employee commitment.

Most effective ZD programs seek to imbue the employee with confidence—in the company, program, management and himself. Thus, the entire ZD approach is based on finding out "what's wrong" rather than "who's wrong," and this reinforces employee job security.

With employees from all levels helping to determine performance yardsticks, primary motivation will tend to start from the bottom and rise up. However, employees must be willing to accept the standards set by management, and management must be willing to help employees achieve these standards, which must be expressed as precisely as possible and reiterated as often as needed. Accurate and frequent comparisons of performance against the standards are vital to sustaining program interest and support.

Employee commitment is further assured by suitable performance recognition. People take pride in accomplishing a task and in doing it well. They work best under positive incentive. Appropriate recognition is therefore inherent to a successful Zero Defects program. Higher wages, promotions, increased responsibility and greater status are often the logical outgrowth of high performance. But studies show that people are sometimes equally proud of achievement awards and merit citations. Of course, the award itself must have stature if it is to instill pride—and the choice of award must suit the circumstances. It must also be personalized: recommended by supervision, presented by management. Conversely, a policy of "virtue is its own reward" can lead the program to limbo. In any case, if a ZD program seems less effective than it should be, it is usually wise to examine the approach to employee relations.

The Manager—His Role and His Tools

Good employee relations usually stem from the way top management relates to its subordinates. Of course, there are exceptions, but when a manager is wholeheartedly involved in a program such as ZD, on a personal as well as a corporate basis, he is much better prepared to help others become involved. His commitment reflects downward through the ranks to assure program acceptance on every level. He must demonstrate also that his own performance standards are firm and exemplary; otherwise, his call to his subordinates for performance improvement is bound to fall on deaf ears. Thus, in the cooperative effort of achieving Zero Defects, the manager projects the standard—as a believer, a definer and a performer.

Consistent with the need to show personal commitment, an early task of the manager is that of functional evaluation—weighing the function and organization of each of his duties against the company need. While he determines the specific tasks, tools and improvement targets, actual performance goals should be established jointly with his subordinates.

How does the manager define and implement this task? One very helpful tool is the Pareto analysis. This technique helps establish improvement action areas, separating the "trivial many" from the "vital few," making it possible to attach priorities to the problems encountered. The ZD effort, then, can concentrate on solving "first things first." Consider the mass of information shown in Figure 1 reduced by Pareto methods to usable management data in Figures 2 and 3.

Figure 1 is one department's quality report, presenting a matrix of the type of problems revealed on inspection and the area responsible for each. A good summary of the month's activity—it reports every complexity and thereby reduces its effectiveness as a management tool. Fortunately, it is possible to break this chart into the readable, relevant terms shown in Figures 2 and 3. By grouping the data, it is possible to identify the incidence of defects according to their component characteristics. Figures 2 and 3 are just two of the early steps in the full Pareto treatment applied to the data in Figure 1. (In this case, the final analysis yielded the somewhat startling intelligence that 662 of the original 913 charted defects could be attributed to two of the ten possible sources.)

RESPONSIBILITY		QUANTITY OF DEFECTS/RESPONSIBILITY MATRIX																								Total Defects	Percent of Total Defects
		Appearance	Circuitry	Component Int.	Configuration	Damage	Distortion Test	Dimension	Drum	E.O. Change	Functional	Hardware Int.	Heat Treatment	Life Lim. 11	Miscellaneous	Non-Defect	Plating	Pol. and Eng.	Raw Material	Soldering	Sub-Assembly	Weld and Brazing	Wiring (Min)	Wiring (Max)	Code Not Assigned		
100	Tooling																										
100	Supplies																										
100	Unassignable																										
100	Machine Shop																										
100	Spec. Mat.																										
100	Special Mfg.																										
100	Plant Shop																										
100	Precision Assembly																										
100	General Assembly																										
100	Thermo Bonding																										
100	Bored and Scrap																										
100	Color Model																										
100	Electrical Mechanical Fabrication																										
100	Communication Power System Test																										
100	Logic Circuit Testing																										
100	Solder Testing																										
100	Product Control																										
100	Material Planning																										
100	Support Group																										
100	Electrical Planning																										
100	Tool Design																										
100	Tool and Test Equipment																										
100	Planning and Mfg. Cost																										
100	Product Control																										
100	Product Control																										
100	Assembly Planning																										
100	Assembly Operator Eng.																										
100	Test Planning																										
100	Test Operation																										
100	Product Engineering																										
100	Process Engineering																										
100	Test Engineering																										
100	Test Engineering																										
100	Mechanical Integration																										
100	Electrical Integration																										
100	Quality Assurance																										
100	Material Proc.																										
100	Engineering (Electric Division)																										
100	Engineering (Mechanical Division)																										
100	Other																										
100	Not Assigned																										
Total Quantity Per Type		19	20	31	16	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	
Percent of Total Defects		9	10	15	8	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6				

Figure 1. Department Monthly Quality Report

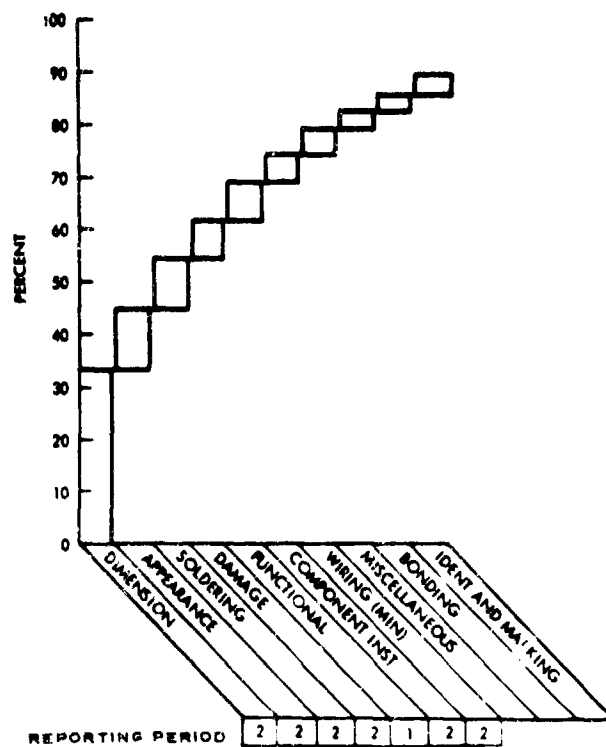


Figure 2. Occurrence of Defects by Type

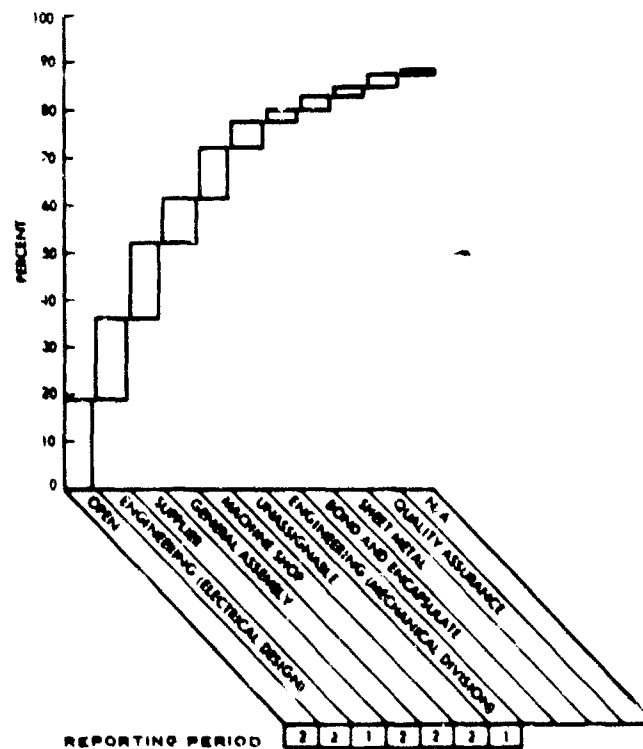


Figure 3. Occurrence of Defects by Responsibility

Statistics like these are, of course, valuable to measuring performance improvement. But without simplification, the statistics would be hidden in the maze of extraneous data. Once observable, however, the information allows company's process control activity to concentrate on those areas requiring maximum attention. And when organizations can devote their time to the most important problems, significant improvements result.

Industrial Engineer/Behavioral Science Techniques

Another approach that has been used successfully is a coupling of work measurement techniques which are normal to industrial engineering with behavioral science techniques which bring out the human relations needs. In applying the industrial engineer/behavioral science approach, management makes certain assumptions about how people relate to their job and about their commitment to achieve organizational objectives. Individuals are seen as wanting to take initiative and to seek out and accept responsibility. They are seen also as being concerned about their work and as having the ability to participate in decisions regarding their work. A comparison of the traditional industrial engineering approach with the combined approach is shown in Table 1. Consistent with this the industrial engineering role is one which recognizes that line management is responsible for use of the program and the controls developed are meaningful only if they are meaningful to him. In this role the industrial engineer is a technical resource to the supervisor. The supervisor identifies his problem, determines solutions and plans the program, calling on the industrial engineer as an advisor.

The approach to time measurement and assumptions about the objectives of time measurement are different:

Management believes that time measurement is an aid
to the Line Supervisor —
not a club in the hands of his manager.

Management believes that time measurement is an aid
to improve productivity —
not a cleaver for cost reduction.

Table 1. Work Measurement—Methods Comparison

Traditional Approach	Combined Approach
1. Cost reduction is the main objective.	The objective is to find better tools (for the line supervisor) to apply in the performance of his required responsibilities, especially cost and manpower control.
2. The program is imposed from above.	The program belongs to line management. (The industrial engineer is a professional consultant to each level of line management, particularly to first line supervision.)
3. Industrial Engineering decides the technique of measurement, what will be counted, etc. The line supervisor contributes only his knowledge of operations.	The line supervisor is involved in day-to-day decisions on what to measure, how to count it, what measurement technique to use, and the reporting system.
4. Performance reports are issued by the Industrial Engineering Department concurrently to all levels of management. Industrial Engineering often explains the variance in levels of performance.	The performance report is forwarded by the line supervisor to his superior. The supervisor is responsible for any explanation with assistance from the industrial engineer when desired.
5. Standards (and the resulting performance reports) motivate increased productivity. (Carrot and Stick approach.)	High levels of productivity and effectiveness cannot be achieved by standards only. Standards by themselves can be negative motivators.

Management believes that time measurement is a means
to an end—
not an end in itself.

Second, the approach to accomplish time measurement is different:

Management will help the Line Supervisor decide what to
measure and how to measure it—
but will not make these decisions.

Management will help the Line Supervisor gather the data
necessary for time measurement—
but will not do it for him.

Management will help the Line Supervisor to analyze the
data and develop meaningful standards—
but will not do it without his participation.

Finally, the recommendations regarding the use of standards for
performance reporting are different:

Management recommends that performance reports be
issued by the Line Supervisor—
not by an outside staff.

Management recommends that performance reports function
as a method of "self measurement"—
not as a measure of someone else.

Management recommends that performance data assist
the decision making process—
not become the sole criteria for it.

To accumulate the work time data an Activity Log is maintained by each person during a sampling period of two or three weeks while the supervisor conducts a work sample study. Figure 4 shows an example of an individual activity log. Every 15 minutes the person marks his activity according to a code. At the end of the day, the data from these activity logs is accumulated either by computerized compilation techniques or by hand on a daily input form. The supervisors work sampling consists of a brief periodic review of activity throughout his area, indicating activity at that moment. The results are summarized and compared weekly to the results of the activity log data. When the work sampling is analyzed and is discussed with those who took the data, it is possible to establish work standards for those tasks which show reasonable correlation of data. Some of these data point out problem areas. These are also good source data for creative group discussions which result in performance improvement.

Name: <u>John Smith</u>		Date: <u>2/11/66</u>	
Dwg Group No. Code: <u>130*</u>		Dwg Type Code: <u>37**</u>	
Dwg No. Prefix: <u>T</u> Body: <u>220081</u>		MJO: <u>2430</u> SO: <u>02</u> UI: <u>01</u>	
Dwg or EO Rev Letter: <u>A</u>			

Period Ending	Activity Code **											
	01/01	12	15	17								
8:45	X											
9:00	X											
9:15	X											
9:30		X										
9:45			X									
10:00			X									
10:15				X								
10:30				X								
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4:15												
4:30												
4:45												
5:00												
5:15												
5:30												
Totals	3	1	2	2								

***Drawing Group Number Codes are three digits to record the following:**

First Digit	Function
0	Administration
1	Checking
2	Designing
3	Drafting

Second Digit	Group
0	Administration
1	Power Equipment
2	Ground Equipment
3	Communications Equipment
4	Guidance Equipment
5	Product Integration and Test
6	Special Projects
7	Runner
8	Clerical

Third Digit	Drawing Level
0	Formal, released drawing
1	Pre-released or preliminary drawing ("X")
2	Upgrading drawing (removing the "X" prefix)

**** Codes can be developed according to group needs.**
Note: Indicate rework, a Rework Code shall follow the Activity Code. 01 indicates the first rework, 02 the second, etc. For example, 01/01 = the first recheck of a drawing or EO.

Figure 4. Daily Activity Log

The Work Unit Measurement Program provides an efficient, flexible method for collecting accurate work time data from the various design and drafting groups and for reducing this data into computer tab runs. When a complete range of data is available, it provides management with three extremely valuable tools:

- a) A detailed breakdown of all design and drafting activity during the working day which shows how personnel actually spend their time (in terms of total man-hours per activity). This visibility highlights particularly time-consuming activities, actual and potential problem areas, etc. The breakdown is useful as the basis for improving standard practices, streamlining operations, and increasing effective cost control.
- b) A comprehensive list of standard times required for the preparation and checking of each type of drawing. Based on actual past performance data, and constantly checked against current performance, standard times can be utilized for more accurate manpower forecasts and more efficient work assignments. In addition, they can help to provide better criteria for personnel evaluations.
- c) A weekly performance rating for each individual design and drafting group. This rating is derived by applying standard drawing times to the number of drawings completed during the week to compute the total earned hours. The actual hours charged by the group for the week, excluding supervision and clerical support, are then measured against the total earned hours to obtain the performance rating by the formula:

$$\frac{\text{total earned hours}}{\text{total actual hours}} \times 100\% = \% \text{ performance efficiency}$$

For example:

$$\frac{1325 \text{ earned hours}}{1540 \text{ actual hours}} \times 100\% = 86\% \text{ performance efficiency}$$

This rating can be used to monitor the validity of standard times by comparing them with actual performance, develop specialized time data for follow-on or minor redesign programs (versus new projects), provide early warning of potential problems, etc.

By varying the data collected (that is, changing the activities reported) the Work Measurement Program can be adapted to changing situations or tailored to different organizations. Currently, computer programs

have been developed which have a built-in updating capability; that is, the programs provide for the automatic comparison of the latest data with that previously collected to continually verify the standard time figures used. This flexibility assures greater confidence in the results achieved, better analysis of the data compiled, and generally more effective use of the data.

Implementing the program requires careful orientation of all personnel. This is to make certain that all management understands its "hands-off" role, that supervision understand its initiating responsibility, and that all employees fully understand the purpose of the program and how they will participate in all phases of the effort. To help gain employee confidence that management is interested in improving work situations, management must follow up the suggestions brought out by individual interviews. This feedback is used only with the permission of the employee. Also data collected during the time-data collection phase is acted upon by management only after employees have first evaluated and commented on the data. Throughout the time-standards development phase, this identification of the program as the "employees' own" is maintained. As a result, the employees help develop correction and improvement of work situations. Also they willingly accept the final standards as well as time allocation of nonproductive work.

Understanding Defects and Their Causes

And so enlightened ZD strategy dictates a rational look at the relationships between defects and their causes—human or otherwise. The following are some suggestions to help clarify the look.

Rising Reject or Defect Rate . . . a sure sign that something is wrong somewhere in the organization and that corrective action must be taken immediately.

Unchanging Reject Rate . . . constancy in a continually changing environment can be a forewarning of something worse. Meanwhile, people are complacent; they accept the status quo.

Housekeeping . . . personal pride shows itself in a number of ways and the most obvious is the way people keep their work areas. Are they neat? Is their equipment in good order? (Sometimes, good housekeeping is a sign of nothing being accomplished, but that is rare. Correspondingly, the cluttered workbench or table is not always a sign of a sloppy thinker or worker.)

Safety . . . rashes of minor injuries, burns and abrasions, damage to equipment. Among other things, these are signs of distraction, showing that people have their minds on other things—not the job.

Down Time . . . drafting machines need an unusual amount of cleaning or maintenance; lathes, drills and milling machines are in repair nearly as long as they are in use; soldering iron tips get blunt faster; flux needs remixing often; operating manuals get misplaced; wire gets tangled. All this can mean that people have given up trying to improve.

The foregoing signs are obviously related to performance and can be measured directly by counting the product as it goes out the back door. Often as not, these signs are evident to supervision, but the real challenge lies in detecting the less obvious signs that people are not producing to full capacity.

Tardiness . . . can indicate laxity or lack of interest. Supervision should first determine which of these bad working habits is "Johnny-Come-Late's" problem.

Coolness Toward Supervision . . . does the work area grow quiet when supervision walks in? Is there no openness between supervision and subordinates? Is there an air about the work area that is hostile and alien? No one cracks jokes? If so, supervision should find out why people are reacting this way.

Requests for Transfer . . . discontent manifests itself in many ways, but one of the more tangible is a flow of transfer requests. If the move is a lateral one, with no apparent gain in salary, status or responsibility, the problem may rest between the individual and supervision. In any event, there is a problem.

Indifference . . . a shrug of the shoulder can mean many things, but the more common interpretation is that the shrugger doesn't care about himself, the job or the people about him. He's completely passive, has no interest in developing a career. He doesn't cause any change; he doesn't ask why or how. He believes "to err is human" and he is as human as they come. Such an individual is acting unnaturally. Supervision's responsibility is to find out why people don't care. It is normal for a company to try to encourage questioning, try to promote growth, try to make opportunity available to any who wish to seize it. We are proud of the mail courier who rises to production supervisor. If the people can't be stimulated into accepting this way of life, the cause could be the stimulant (or stimulator) and not the person supervision is trying to stimulate into excellent performance.

Since the purpose is to achieve results through the efforts of others, management must involve full recognition of human values and individual personalities. This is especially true in the Zero Defects context, where various managerial duties are vested in the employees. Therefore many management functions are necessarily more subtle as they apply here. Certain responsibilities are management's purview; some are employee exclusives. But many others overlap organizational echelons to devolve on management and employees together for a cooperative vertical effort, the only effective kind.

Zero Defects and Human Relations

Since the philosophy of Zero Defects is essentially one of prevention rather than detection, solutions invariably involve human relations. The manager must be able to sense "people problems" as they affect performance, to distinguish human error from what may appear to be mechanical malfunction.

Much has been written about organizations spending countless dollars retraining personnel and replacing equipment, only to find the results are minimal. In such cases, so they say, management seems all too eager to ascribe high defects to inferior skills or bad machinery—and little effort is made to isolate the human errors. According to this belief, a simple communications problem may masquerade as one of training deficiencies—or a morale breakdown be ascribed to inoperative machines. Even well-trained employees working with good equipment under favorable conditions make inordinate errors—when they are demotivated, etc., etc., etc.

So goes the theory. In practice, the opposite is often the true situation. Overzealous ZD practitioners often harp on human error to the near exclusion of any other possible cause. They forget that the most highly-motivated man in any company can't do the job with a broken tool in his untrained hand.

Of course, the manager must have the authority to implement the goals he outlines, to produce the results for which he takes responsibility. Without diminishing this authority, a good ZD program demands sustained

management support to employees. Behavioral psychologists point up the close connection between motivation and morale. To provide the type of working climate where both will flourish, there are many options open to the manager. As we have said, one of the most important is an examination of his own motivational levels. It is important to ask first, how high are the manager's standards. The answers must vary, because everyone from assembly line to executive suite spends more time and energy on matters related to his interest or skill. But subordinates will rarely exceed the standards set for them by supervision; therefore, motivating other people starts with motivating managers. Indeed, the very science—or art—of motivation is the subject of countless books. But while this wealth of literature is analyzing causes and prescribing techniques, the everyday business of motivation comes down to one basic fact: to motivate others, you must communicate your own commitment.

Research has shown that the key to influencing better job performance is the relationship between employees and supervision. Perhaps this is too simple a formula for success. It says people should be able to talk to each other and understand each other's motives. But understanding also means people should be able to listen to each other -- and that's the hardest part of all: listening. Ample evidence shows that people have built-in filters. Some supervision cannot fully understand instructions coming down to them. Result: the translation to their subordinates is faulty, and performance suffers. Filtering of communications is a common obstacle to performance improvement at any organizational level.

But communication goes two ways. The same filtering action often occurs when the word is being passed upward, from subordinate to supervision. The manager must be willing to examine employee-initiated improvement suggestions. And when these ideas show evidence of value, he should help gain their acceptance and implementation. Thus, motivation through communication—the ability to talk and listen to people—cannot be overemphasized.

Assessment of Results

Assessment of the effectiveness of the ZD program involves two different aspects:

- 1) Acceptance of the program
- 2) Results and achievements catalyzed by the program

The meeting of company goals for performance improvement is certainly the more important area to assess. However, long before consistent results are measurable, it is possible to evaluate the effectiveness of program activity.

Initial observances do not vary much from one organization to another: gala kickoff rally, indoctrination by supervision, all-hands enthusiasm, signing of pledges, posting of slogans. But when the shouting is over, what do employees, supervisors and managers really understand about the program objectives, the purpose of program activity, the personal commitment required, the in-line operation, and job-related activity intended?

It is normal for each person to hear and interpret according to his interest, modified by his environment. So when the program says, in effect, "talk over your suggestions and performance problems with your supervisor," the employee may well reply to himself "My supervisor?—he's not interested."

Misinterpretation of company intent, obscure management backing, supervisor indifference, or employee resentment can seriously impede the progress of the misled and those who interface with them. Therefore, early detection of these program pitfalls is essential.

The best means for determining where program acceptance needs attention is for the program administrator and broad-organization coordinators to sample the opinion of employees which direct questions:

"What is the program all about, as you understand it?" (The disparity of answers to this one may astound you.) "Do you think the program is properly pointed; does it have the right activity to accomplish its aims?" "What do you think should be done to make the program successful?"

Any deficiencies in communicating and implementing Zero Defects will bubble right up from the answers to questions like these. There is no better way to pinpoint the areas where specific redirection should be applied. More often than not, reorientation of supervisors is needed, or management support needs strengthening, or increased commitment of interfacing organizations is required. These problems should be dealt with specifically as the need is revealed; the right remedial measures will eliminate demotivation, giving group initiative the freedom to achieve and improve.

Even when program activity is generally well established, it is important to continue sampling the understanding and direction of the program as applied to each organization. A constant hazard is the human tendency to drift away from self-critical job-oriented performance improvement effort toward deceptive external evidence of activity. Posters or slogans, contests and games can stimulate awareness and understanding, but involvement of employees in generating these, rather than looking at their own jobs, amounts to misdirected effort.

The first step in assessment of results is to make sure that the performance trend indicator—the measurement basis—is actually sensitive to the quality of the work being measured. Naturally, no single norm will apply to every work function. Since Zero Defects involves all employees, job responsibilities vary widely; therefore, measurements must suit the variable characteristics of specific groups. It is sometimes difficult—but always important—to find the most valid gauge of measurement. Think of it as an index to the health of the entire system, rather like the human pulse. Once chosen, the right criteria will facilitate the choice of action needed for achieving the predetermined goals.

An outstanding example of company-wide adaptation of this flexible approach is shown in Figure 5. Here the selection of goals coordinates with the functions and needs of the various organizations. In this case, the personnel "own" the basis and see themselves in the trends. Finally, they feel pride in achieving their goals—because the yardstick used to get them there relates to their individual interest.

BASIS FOR MEASUREMENT	ORGANIZATION								
	FIELD OPERATIONS	FINANCE	RELIABILITY CONTROL	INDUSTRIAL RELATIONS	TEST OPERATIONS	LAUNCH VEHICLES PROGRAM	RESEARCH AND ENGINEERING	MATERIAL	TOTAL
BUDGETS	4	7	4	1	7	9	10	9	51
METHODS	4	11	12		6	4	2	1	40
TRAINING	10	1	12	1	20	2	25		71
COST REDUCTION/ES	42	5	36	5	26	14	24	4	156
SCHEDULES	8	5	2		15	33	34	18	115
SAFETY	14			1	10	11			36
HOUSEKEEPING	11				16	1	8		36
ENGINEERING PAPER	5					49	30		92
MANAGEMENT TECHNIQUES					5		4	4	13
QUALITY TRENDS	18	16	13		21	68	27	15	178
ATTENDANCE	6		2		11	6	7		32
CONSERVATION		1			2		1		4
WORK MEASUREMENT	11	6	28		20	25	6	6	102
DAMAGE CONTROL	8					2			10
NEW BUSINESS							35		35
OTHER	3	2				2			7
TOTAL	144	52		8	159		221	57	978

Note: Numbers indicate quantity of measurements per organization.

Figure 5. Comparison of Various Organizations' Measurement Goals

This is a happy contrast to the sanitized performance charts (see Figure 6) in which the goals are always a flat 100 percent, performance is always a percentage thereof—and goal bases are always unseen. This method of charting helps develop company-wide uniformity as a basis for competition—and also helps to hid objectives so the focus of the group shifts away from self-examination and striving for excellence, to comparison with others and competition for awards. Certainly competition can gain results, but once the competition ends, so does the incentive. However, the self-motivation approach pursued in Figure 5 develops new levels of performance that soon become accepted standards.

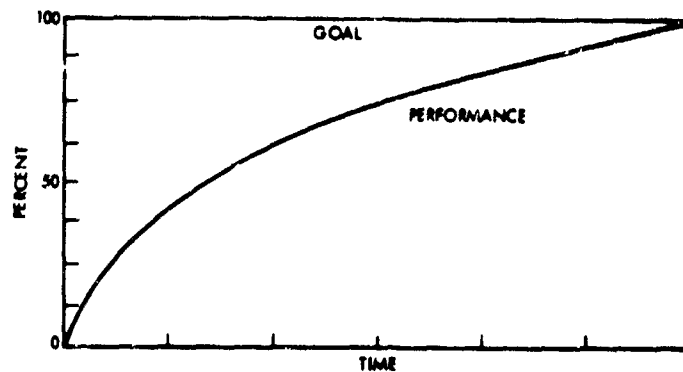


Figure 6. Sanitized Performance Chart

Another assessment checkpoint is supervisory and managerial response to visible performance trends. When an improvement need appears, does the supervisor do something about it? Does his manager help when needed? Indifferent results are often traceable to indifferent supervision.

It is equally important to be sure the ZD effort is being applied to every step in the flow of work through a unit. Perfect output cannot be produced from imperfect input. To eliminate defects in its own performance, a unit must make sure that each step in its work is under proper control; perhaps instructions, checklists, procedures, and facilities can be improved to achieve this. During this process it often becomes evident that the input of work is defective; instructions are imprecise, incomplete, or inaccurate; material to be processed is defective or wrong. The unit receiving this caliber of input can improve its performance and help the upstream performance by refusing to accept the work until it is submitted correctly. High performing groups take this stand as a natural way to operate. Low performers, if this is a contributing cause, can blame themselves for accepting low-quality input.

An essential assessment point is how well ZD integrates with other management programs, such as Cost Reduction, Value Engineering, and Industrial Engineering. To obtain full value from each, it is imperative that these programs maintain a proper working balance (see Figure 7).

ZD's primary objective is performance improvement. One natural result is cost reduction. The Cost Reduction program concentrates on improvements in process, methods, or material, each leading to lowered costs. Value Engineering uses function-value analysis and study of

alternatives to attain cost effectiveness. It can be seen, then, that these programs have much in common, are mutually supportive but not redundant, yet apply different technologies. Operational synergism can best be obtained by coordinated effort of all three (see Table 2).

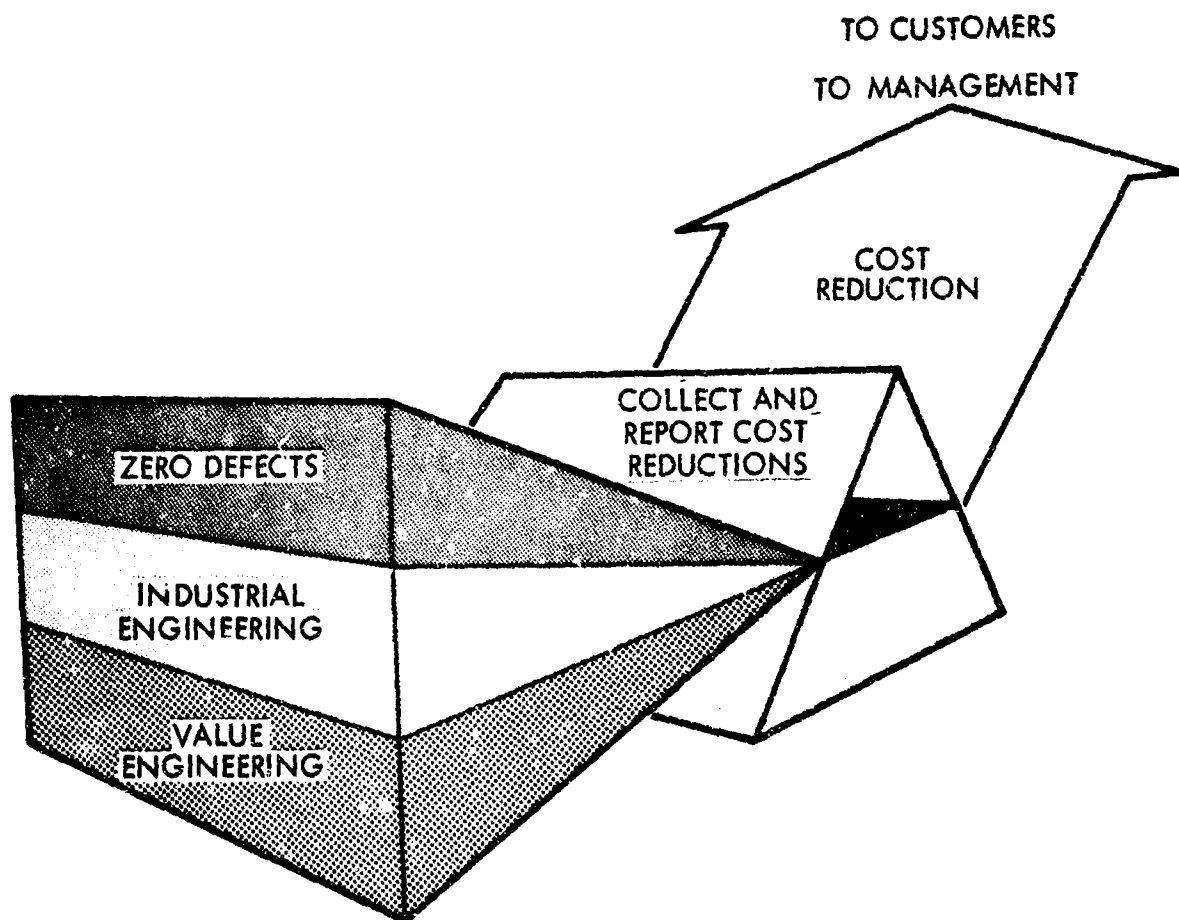


Figure 7. Integration of Programs for Coordinated Effort

The charting and display of performance trend data can serve as an automatic appraisal of results, and at the same time keep the members of the group aware of the status of their effort. The chart should display clearly-understood parameters. For example, the simple score of defects per man per week (d) charted each week is well understood by participants and interested visitors (see Figure 8). This factor is usually calculated as follows:

$$d = \frac{\text{total defects this ek}}{\text{total hours worked}} \times \text{hours per man-week}$$

Table 2. Comparison Chart

Criteria	Cost Reduction	Value Engineering	Zero Defect Program
1. Objective	Establish optimum cost levels through the creation of operational efficiencies that reduce cost	Achieve sup for cost performance, cost savings, and increased profit through the use of functional analysis and other value engineering techniques.	Voluntary achievement of excellence in job performance
2. Goals	Dollar goals—achieved by developing and improvement in a process, method, or material	Dollar goals—achieved through individual and group cost effective performance and through profit realization from VE contract incentives.	Performance goals set by individuals and groups to improve their quality, schedule, and cost performance
3. Plan of Action	Analyze items or areas of costs, listing potential cost reduction projects Assign responsibility to an individual or a group to take action to develop a better method, material, or process. Manager of section follows progress of projects, adding or closing out projects monthly.	Create a general climate of cost sensitivity and awareness for profit from VE contractual provisions. Equip individuals with the "tools" for cost performance in services and products produced. Conduct value studies (VE projects) on items exhibiting cost problem or low value. Develop lists of areas of opportunity for value improvement, utilizing value engineering resources, potential cost reduction projects, RFI's and other sources as appropriate. Assign individual or group to assume action responsibility on identified "areas of opportunity."	Communicate to employees the objectives, philosophy, and potential of this effort. Encourage each employee to systematically look at his job, his knowledge and skills, the tools he has or needs, the methods and procedures involved, and his accomplishments against requirements. Employees in cooperation with supervision develop and perform tasks aimed at group performance improvement. Remove causes of error and other roadblocks to excellence in job performance. Establish measurement able to indicate performance trends. Review results and take appropriate action. Give recognition for achievement. Whenever a reportable cost reduction is achieved it is reported through Cost Reduction program channels.
4. Measurement of Progress against Goals	Dollar achievement against goals. Report on monthly reports down to department level.	Dollar achievements are documented under the Cost Reduction program and through a customer approved Value Engineering Change Proposal.	Performance trends by chart as appropriate. Review periodically. The activity characteristics charted are those most directly representative of the quality, schedule, or cost performance of the group.
5. Effect on Employee	The MPS merit review would be affected either (+) or (-). The clerical and support merit review would be affected (+) only.	Same as under cost reduction	An employee develops pride in accomplishment, gains recognition for achievement, and has self-confidence in his ability to perform his job in an outstanding manner.
6. Employee Participation (who participates)	Expected contribution basically from MPS personnel. Encouraged contribution from clerical and support personnel.	Same as under cost reduction	Each employee strives to meet the challenge of doing his job the right way the first time.
7. Primary Focus	Focus on cost reduction (collection and reporting).	Focus on cost effectiveness (cost reduction techniques/methodology)	Focus on performance (motivational program).

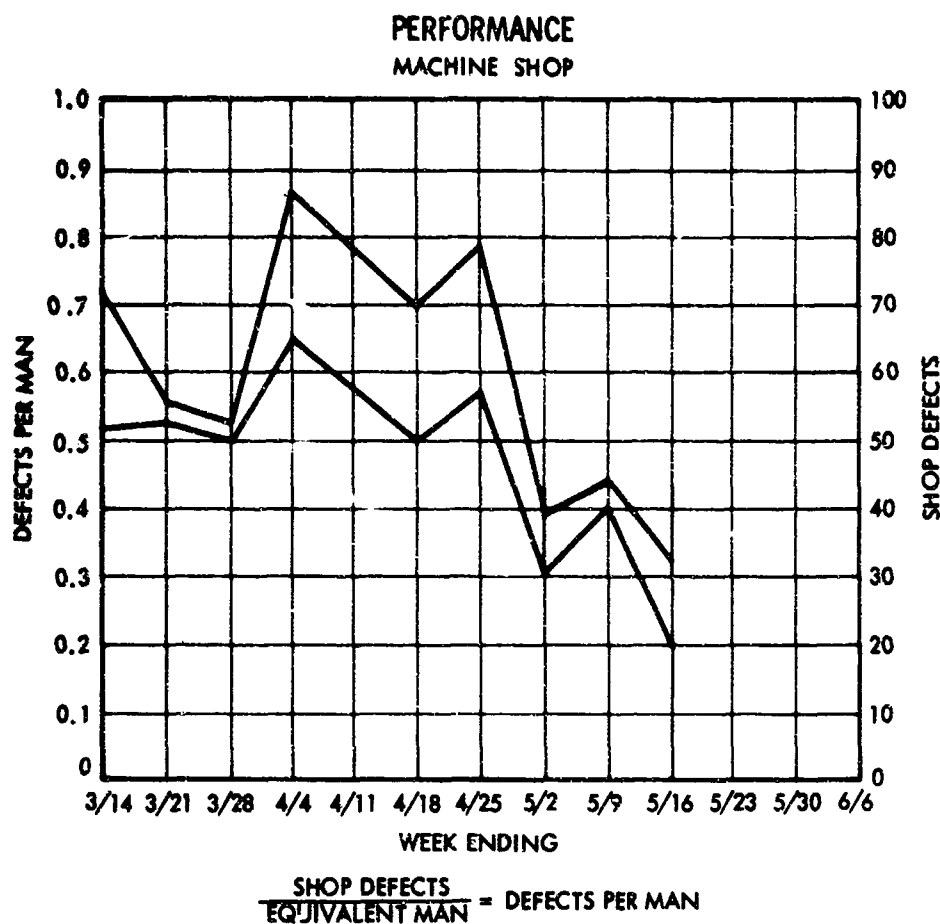


Figure 8. Defect Rate Performance Chart

As group performance approaches the Zero Defects level, *d* becomes so small that groups just chart the occasional defect. But enroute to this achievement level are many sources of error which must be controlled. The program appraisal would be incomplete without at least a cursory status check of typical error sources such as:

Specifications	Methods
Procedures	Processes
Facilities	Tools
Housekeeping	Arrangement
Working environment	Training
Purchased materials	Company standard practices

Individual performance can be charted as shown in Figure 9 where the employee sets his own goal and records his own achievement.

PERFORMANCE

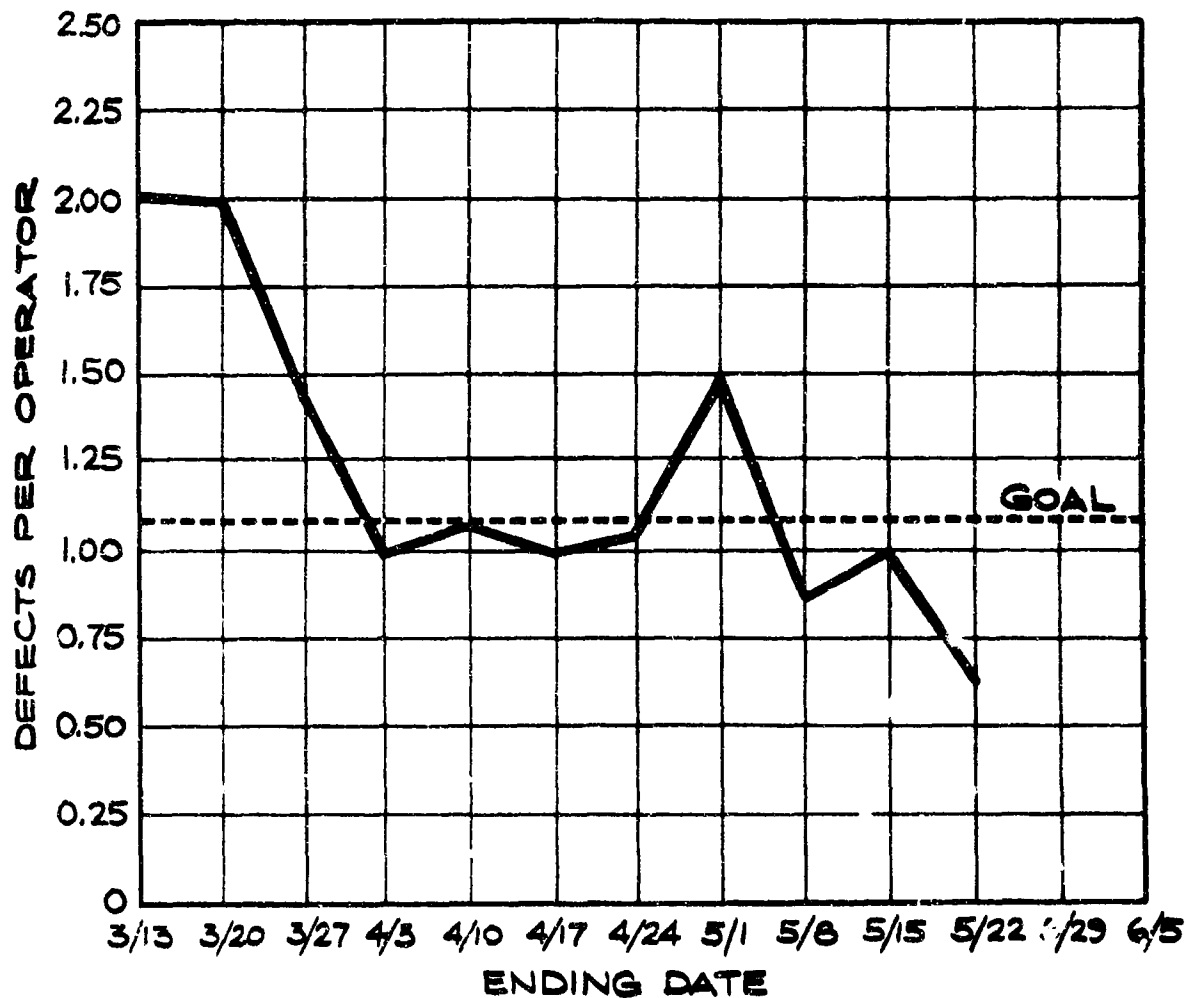


Figure 9. Employee-Set Goal and Achievement

Nor is performance trend data limited to defects and error sources. Job characteristics are also rich in measurable performance criteria. Appendix A is a comprehensive list of appropriate characteristics for different functions. This compilation can serve equally well as a checklist for judging completeness of program coverage.

Of course, the ultimate test of any Zero Defects operation lies in the realm of concrete achievement—that happy land of improved product and performance, where morale is up and errors down, with schedules met, budgets balanced, goals fulfilled. A place so crowded with wonderful things, there is hardly any room for improvement!

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QUALITY EDUCATION PROGRAM

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This text treats the philosophies, objectives, attitudes, and disciplines of product quality. It is directed toward the basic training problem, the implementation of a quality education program, the evaluation of that program, and advanced training techniques.

Any education program must be tailored to fit each situation. The information presented here represents a typical approach and could be used as a guide in developing specific quality education programs.

The Basic Problem

"If at first you don't succeed, try, try, again," expresses a luxury enjoyed by past generations of people and products. Today we can no longer afford that luxury.^{1*} In nonmilitary products, where customer satisfaction in a highly competitive field can make or break a company, there is no opportunity to succeed on the second, third, or fourth chance. The customer's reaction is, "if at first you don't succeed, change brands." Similarly, if the product is a military defense weapon or is intended to make life more comfortable, quality is what counts. Assuring that quality reflects favorably on the manufacturer requires appropriate motivation of all who can influence quality. Appropriate communication, up, down, and laterally in the organization, and appropriate knowledge of quality is required. This requirement can be met through an appropriate quality education program.

Nature of the Need

Customer satisfaction is not a one shot event. Nor is it limited to the psychological reactions at the time of delivery. Rather, customer satisfaction is subject to reversals throughout the life of the product. Merely establishing the proper climate for manufacturing a product to warrant customer satisfaction does not guarantee that satisfaction will

* See reference list at end of paper.

last indefinitely. The quest for quality and customer satisfaction is continuous. There is no one-time cure or single fix that will assure quality. Continuity of quality awareness, more than any other factor, demands continued education; education that must emphasize the prevention of defects or undesirable features with detection used as a control device.

Motivation

Positive quality attitudes in an organization are reflections of the very intangible and extremely important spirit of "quality mindedness" extending from top management to the workers at the bench.² These attitudes can be attained through the process of responsible "selling" by the proponents of quality. Whatever is new about the total quality program is gradually introduced, step by step, to the entire organization so as to obtain its willing acceptance, cooperation, and participation. New and unfamiliar quality procedures are introduced in the shop only after considerable forewarning and smoothing of the way. Descriptions of quality technical methods are presented in shop talk instead of in the mysterious language of the mathematician or technologist. Selling the total quality program is a matter of sound human relations. It requires clear, concise, and sustained communications with all persons and groups who have a role in total quality.

At least four general considerations must be taken into account during development of a successful quality program:³

Individual Tailoring. The organization's quality needs should first be carefully analyzed. The quality plan to be introduced should contain procedures and terminology tailored to the individual requirements determined from the analysis. It should not be a "prepackaged" program lifted bodily from another company or from available literature.

Economic Balance. The quality activities proposed in the plan should be based upon sound economic analysis. Its scope should be a balance between the range of quality problems and the cost of the minimum amount of control required to solve them. Problems of acceptance when describing proposals in technical terms diminish quickly when their potentialities are expressed in the business language of quality costs.

Participation. The quality plan should recommend action and require cooperation from many functional groups and persons in the organization. Action, cooperation, and motivation of these people and groups are more likely to be secured when those immediately involved have participated in the formulation of the plan and of the quality program it recommends.

Emphasis upon Benefits. The plan should emphasize the tangible benefits that may be derived from maintaining quality and should indicate the measuring sticks that will be used regularly to evaluate the results produced. Citing actual applications of individual quality projects that have been successfully carried on in the organization will enhance the salability of the entire plan.

Attention should be directed to why the quality proposal is being initiated. Understanding the underlying reasons should strongly influence the approach planned for introducing the program. For example, sponsorship by top management will encourage spontaneous and genuine approval and effective participation by the lower echelons of the company. In the absence of their endorsement, functional heads run the risk of creating the impression that total quality is simply an "empire-building" device.

Determination of Needs

The suggestion that an organization undertake a total quality program may come from any of several quarters. It may be initiated by top management because it sees the necessity for improved quality or has seen it work in other organizations. It may be proposed by functional heads or by relatively young technical specialists.

The proposal to initiate a total quality program may be a defense mechanism in the face of severe pressure on the organization. That pressure may be in the form of increasing field complaints, extremely high manufacturing losses, or growing personnel disagreements caused by unresolved quality problems. The initial proposal may be made as a suggestion to improve an already operating series of activities directed toward the control of quality.

Regardless of the source or reason of need, the first major task is obvious and universally practiced. A practical plan must be developed for outlining the objectives of a total quality program. It must convince top management that total quality prospects are attractive and beneficial enough to "give it a try."

Program Evaluation

Key Personnel Characteristics Required

The design, manufacture, and support of products of consistently good quality require a high degree of effectiveness in at least three key characteristics of participating personnel:

Their Quality Attitudes. Essential here is the genuine belief by employees in the importance of good quality, excellent workmanship, well-conceived designs, and service-centered support.

Their Quality Knowledge. Vital in this connection is employee understanding of the kinds of quality problems that bear both upon their individual jobs and upon the company. Further, the desire to transfer knowledge gained into job-related activities is a desirable characteristic.

Their Quality Skills. Important here are the abilities, both physical and mental, through which personnel actually perform the operations essential to quality.

A company whose employees have sound quality attitudes, keen quality knowledge, and adequate quality skills is the organization whose work force has the greatest likelihood of designing, manufacturing, and supporting high-quality products.

Quality Education as a Process

Education in the field of quality, with varying degrees of effectiveness, has been taking place in industry in one form or another for many years. Management knows it must begin with the existing personnel's attitudes, knowledge, and skills, however good or bad, and build on this foundation. A regularly functioning, informal learning process will continually add to the fund of knowledge upon which improvement is realized.

Many of the modern quality-education efforts that have proved unsuccessful for American companies during the past ten years have one thing in common. They ignored the principle that to determine where a man or program or quality-education activity is going, it is first necessary to learn where that man or program or educational activity has come from.⁴ Although much attention was lavished on content and teaching methods, the unsuccessful company quality-education activities never really fitted the company for which they were designed. Some were offered prematurely or were not sufficiently down to earth. Others were couched in quality terminology without reference to the traditional plant designations for rejects, losses, and quality faults. Still others took no advantage of the quality-education process that had been going on in the plant for many years. Collectively, they never came to grips with the company and its quality problems as they existed at the time the educational programs were begun.

Experience indicates that the first task for a quality engineer in appraising his organization's quality education is to analyze the existing quality-education process and determine its characteristics, strengths, and weaknesses.

Analysis of the Existing Quality Education Process

The quality engineer must ask the following questions about the existing quality education process during his analysis.

1. "What are the scope, magnitude, and effectiveness of the formalized training for personnel in the specific job knowledge and skills that are required for the designing, building, and maintenance of good quality?"

Even if an organization has a training staff, which may have well-organized answers ready for him, the quality engineer must dig much deeper for his analysis. He should go to the grass roots to find for himself (1) the emphasis placed by the apprentice school on relative types of quality knowledge and skills; (2) the amount of time actually spent in teaching new operators job skills relating to quality; (3) the reaction of supervisors to the caliber of the knowledge and skills gained by employees in such training; (4) the reality of the organization's current quality

problems and of the inspection-training manual used; and (5) the degree to which development and design engineers acquainted themselves with the realities of modern requirements for product reliability and the analytical techniques for dealing with these requirements.

In the absence of a formal company training staff, the quality engineer will have to dig ingeniously to find any kind of training efforts in quality being conducted by organization unit supervisors. It is vital that he establish such facts, for a major purpose of his analysis of the current quality education process is to gain a picture of the total hours—hence total dollars—being expended on formal training for quality.

2. "What is the net effect on the quality thinking of personnel due to the informal, on-the-job, day-by-day influences of experience, contacts, and exposure basic to the process of quality education in an organization?"

The single most useful criterion for answering this question is the degree of quality-mindedness that exists, section by section, throughout the organization. While no techniques for the quantitative measurement of quality-mindedness seem yet to have been developed, quality-mindedness can be sharply and readily appraised qualitatively by an experienced quality man.

3. "What are the scope, magnitude, and effectiveness of the organization's formalized efforts to train personnel in the modern concepts of quality and in the programs and methods of total quality control?"

In the early days of total-quality programming, the typical answer to this question was, "Almost nothing." It remains, however, a very useful practical question to ask. Often material that relates directly to modern quality and its control turns up in some dark corner of a company's educational process. Someone, years ago, may have inserted it in a supervisor's training course. Possibly, some supervisor or workman, to whom the terms \bar{X} , R, or p charts would be a new language, has instinctively discovered the usefulness of charting reject percentages or parts from certain machine tools. Realizing its utility, the supervisor or workman has educated or is trying to educate those around him in the value of

these methods. Such homegrown material, as well as the people who have used and developed it, can be tremendous assets in any formalized quality-training course being planned.

Evaluation of the Existing Quality Education Process

Answers to these three questions provide the quality engineer with much of the basic material he needs for planning the types and kinds of modernization that must take place to bring this educational process up to date. Specific action to be taken in the area of the first question—formalized training—represents a major problem of industrial education in itself. It relates to the quality aspects of training apprentices, intern or student engineers, and new employees. As such, it is more suitable for review in books which concentrate upon industrial education, and it is to such volumes that quality engineers should turn for direction in this area.

Question two—the informal process of quality education—which concerns the various problems of developing and maintaining quality-mindedness, is a major field for quality-control attention in itself.

Question three—the formal training of personnel in modern quality problems and in control techniques—is the issue usually of prime interest to quality engineers who are endeavoring to modernize their company's quality-education process.

Quality Mindedness

One of the three objectives for education in total quality control, as mentioned above, is related to the matter of attitudes.

Historically, quality attitudes of personnel have been shaped by a broad process of quality education which involves not only formal quality courses but also, to a much larger extent, many informal quality influences. These influences are the actions and deeds that occur daily in connection with the job.

The individual is the key to producing products of satisfactory quality. In most instances, he wants to do a good job; and he can and will if the correct "climate" is provided. He looks to his supervisors and managers

to provide the necessary quality system, the tools with the required capability, suitable training for the development of necessary skills, and quality information equipment to measure his performance and guide the operation of the process for which he is responsible. In the final analysis, it is this man—the individual operator—around whom the quality-system plan and quality-education program is designed.

The quality system plan is normally a technological one. The quality education program, on the other hand, assures that the technology is supplemented by a human climate which motivates the individual operators to want to produce good quality. This motivation is largely supplied by the actions and deeds of the supervisor. Thus, unless top management—and all levels below the top—shows continued interest in product quality by deed as well as by word, the individual's interest in additional education and training will drop.

Interest in quality has to be genuine and be borne out by action—by periodic meetings to discuss quality problems, by adherence to the quality policy for the organization, by balanced interest in behalf of product quality, and by a good quality education program. Unless such interest is evidenced, lack of support is felt by those who daily seek to attain quality standards. If this support is withheld for long periods, morale begins to suffer and ineffectiveness inevitably results. Resistance to compromising product quality may disappear when it is most needed.

The functional managers are expected to carry out the policies of top management and, at the same time, do the job according to plan and schedule. Unfortunately, plans go awry and conflicts arise. For instance, a new design may have hit a snag, creating a quality problem as well as a potentially late delivery. Will halfway measures and a temporary fix be used to meet the delivery date? These are the situations that put quality-mindedness and the integrity of the individual on trial. Certain loyalties develop, both to the company and to the product. Functional managers can do much to demonstrate the principles of quality presented in the training courses by their actions in behalf of sound product quality. The education process thus becomes a dynamic influence in management operations.

One of the key people in any quality-mindedness campaign is the shop foreman. He represents first-line management to the people who report to him. If a good employee relation program is working, the foreman's position as part of management is well established, as are also the lines of communication. The employees look to the foreman to keep them informed on the company's problems and successes. Thus, in a quality-mindedness campaign, the foreman is the spokesman for the company. Furthermore, the foreman's actions in behalf of product quality must be backed by the managers all the way up the line. If this support is forthcoming, quality principles taught in training courses will be respected, and the foreman will be sure of his ground and will champion the cause of product quality.

This is the positive situation the worker likes to see. He takes pride in belonging to an organization where the day-to-day actions of his supervisors are consistent with the aims of the enterprise. To him, it typifies a strong company that knows where it is headed. He is challenged as an individual to put his best effort and skill into producing quality products. He knows that because of a quality education process research, engineering, manufacturing, and marketing have done their very best to provide the customer with a product of satisfactory quality.

Implementation of a Quality Education Program

Basic Principles

Adults learn and retain only what they think they need to know: information to help them in their work; skills that help solve the problems which plague them. Therefore, the most effective quality training courses are those that are quality-problem centered rather than quality-theory centered. By adhering to the following principles, the curriculum should, by presenting specifics rather than generalities on quality, help people do their job better.

Principle 1. The accepted principle in building a quality training program is to keep it down to earth and centered upon real quality problems. Concentrate upon practical, meaningful quality case studies.

Principle 2. In developing quality training programs, the quality engineer and training staff should work and consult with the line organization to the fullest extent possible, especially in regard to the scope of and the kinds of material to be used in the programs. The line organization must do the bulk of quality problem solving. Line people should, therefore, be made to feel that course work is being carried on as an assistance rather than as a substitute for them.

Principle 3. The quality training program should be based upon recognition that the solutions to industrial problems—therefore, the solutions to quality problems—are always changing. Accordingly, education in quality methods and techniques can never be considered as completed, including education for the educators themselves. Participants in the quality courses should be strongly encouraged to continue their education on a self-training basis after completion of the formal course. It also follows that the formal quality training program should have definite, organized provisions for periodic, brief refresher courses.

Principle 4. The training program should, in the long run, include and involve participation by all levels of personnel. Since interests and objectives differ widely among organization levels, individual courses in the quality training program should be tailored to fit these several needs. A single quality training course should not be forced to fit such widely different needs as those of the general manager, the quality engineer, reliability engineer, the inspector, and the assembler.

Objective for Quality Education

The basic management objective for quality education is the development in all personnel of attitudes, knowledge, and skills which may contribute to quality production at minimum costs consistent with full customer satisfaction. This is not a new objective. Long before total quality programs had attracted widespread attention, management had emphasized quality in the training of new operators, in courses for foremen and supervisors, and in the types of assignments used in the planned rotation of engineers.

The objective can be partly achieved through formalized classroom training. But much of the quality learning process—especially attitudes, and to an appreciable extent, knowledge and skills—takes place informally. Part of it is forced upon the employee through on-the-job experience. A large part of quality learning comes from daily contact between the man and his boss and from exposure to his fellow workers.

The ways for achieving the management quality education objective vary widely over periods of time. Quality problems have only one certainty: they will change continually. Accordingly, the solutions to quality problems can be likened to a book whose final chapter never will be written. Quality education never ends for the competitive, aggressive organization whose products must survive in the fast-moving world market.

Organization for Quality Education

People learn only as a result of their own efforts. It is not possible to "teach" anything, but an adequately organized training effort can provide the means and the motivation⁵ for learning. Accordingly, quality training must properly define and present needed facts to the trainee in a properly time-phased, well-organized manner.

As in all organized training, the administration of the effort must have a "principal." In the case of a quality education program, the "principal" is usually a qualified education specialist from a special training group or personnel management function within the company. He must, however, rely extensively on technical advice and assistance from the most knowledgeable quality, reliability, and maintainability personnel available.

A viable quality education program must be properly planned and executed by persons professionally qualified and compensated for this purpose. Thus, at the very outset, it is necessary to consider organization for training. In small organizations a single person may be assigned as a training director with full authority and responsibility for training programs. In some instances this could be a part-time duty. In larger companies, however, it is essential that a central training organization

be established. Ideally, such an organization should not be specialized in any given area of training. It is not advisable to have a separate training group, nor is it advisable to have training specialists who operate outside the cognizance of the central training organization. Of course, staff consultations are not precluded between the training organization and various specialized areas of management. It is expected that an "inside" professional organization will be more sensitive to the needs of the various line and staff functions and will not presume to have capabilities in specialized fields. From a quality point of view, the organization responsible for training must be thoroughly informed of management's needs so that appropriate programs will be scheduled with sponsoring elements of the industrial organization.

Since quality education spans both "formal" and "informal" training, the "message" of quality must be directed to the day-to-day supervisor/employee relationships as well as to the programmed curriculum. In normal day-to-day supervisor/employee on-the-job training, the supervisor assumes the role of instructor by providing technical guidance, as well as motivational emphasis, on the importance of a better quality product for the success of the organization. Both the "formal" and "informal" training sessions should stress the basic Zero Defects theme of individual craftsmanship along with the importance of producing products economically and to the satisfaction of the customer.

Planning a Quality Education Program

A good principle to remember when considering a quality education program is that all people are afraid of something they do not understand. While the goals and impact will be known well by the program organizers, they may be mysteries to other parts of the company. Resistance arises from fear. Therefore, the quality training course should dispel the mystery by making people aware of the needs, methods, and, most important, favorable effects on themselves and their jobs of such a program. This knowledge, coupled with adequate assurances concerning their job security and their understanding of the part they will play, will usually

motivate most people into actively supporting the program. Others may accept the program passively. Some, of course, will reject and resist anything new.

In general, the "why's" of an education program for quality are:

To develop an understanding of and a desire to achieve marked improvement in quality of the products destined for military, industrial, and the consumer markets.

To enlarge each participant's concept of the meaning and significance of quality and methods for its achievement and control.

To bring about realization on the part of middle and top management of the problems engineers and others have in attempting to achieve a higher degree of reliability and quality.

To unify personnel into a working team to achieve the goals of the program, i. e., to prevent defective material from being produced.

To ascertain the work in which each contributing member of the team is most successful. In this way he will be capable of the most growth toward still greater achievements in the attainment of improved quality.

To bring into the program new personnel who will be able to translate theory into practice.

To acquire sufficient management discernment to provide immediate help in resolving differences or difficulties that threaten program setbacks.

To make engineering and factory personnel receptive to help and to persuade them to analyze critically and objectively their own activities.

To motivate all people concerned with the program to grow in the direction of their greatest professional effectiveness.

To emphasize the difference between the goals for short-term and long-term programs of growth toward the achievement of built-in quality.

To alert people to needed changes in organization and administration that will facilitate effective programs.

To provide the novice as well as the expert with leads toward unfamiliar sources of ideas and materials conducive to continuing growth in the achievement of improved overall quality.

To assist engineers in diagnosing system and product design problems and to provide help toward planning for growth in knowledge to solve them.

To develop esprit de corps in an organization-wide quality program.

To place in the hands of workers and managers techniques needed to best achieve quality through the prevention of faults rather than through the correction of detected faults.

To assure that program efforts are on a basis of optimized cost and schedules.

Two actions are required to initiate a training program: First, show your subordinates through your own convictions. It is better to inspire, suggest, educate, and follow-up than to direct their compliance. Second, sell your associates. Engineers have a hard time convincing top management, even with well-organized plans, without advance notice and coordination. Stimulate public relations, sales, production, contract people, etc., into being prime pushers of a coordinated quality improvement effort. Try such arguments as: quick product acceptance, coordination with vendors and other producers, faster checkout and delivery, superiority over competitors, desired reliability standards which are attainable, contracts more easily specified and complied with, and better customer satisfactions.

Remember that a formal proposal presentation of a complete program and its effects on all concerned is necessary to obtain management action. Oral presentations may be bypassed without action and pertinent arguments discounted or forgotten. Support all oral efforts with written documentation.

Establishing the Curriculum

The formal courses should appeal to the self-interest and general outlook of each group being trained. If related to the levels in an organization, the courses fall into four categories: (1) top management, (2) middle management, (3) technical and engineering staff, and (4) labor and clerical.

Top Management: A quality oriented training course for top management should be aimed at showing that the program will do the following:

- Improve the product
- Save time
- Reduce costs
- Help achieve schedule objectives
- Improve customer satisfaction

All top management classes must be designed to present maximum material within the economic framework only. All presentations, handouts, etc., must reduce facts to a dollar base and be stated in terms of costs and savings, time schedules, contractual requirement, etc. Attempts to acquaint this level with the total technical aspects of the program will be wasteful. However, when it is essential to present technical material, it should be simplified. Philosophies of a technique should be presented—not the technique itself.

Top management usually has a high degree of understanding. They know that simplicity of philosophy usually is the ultimate result in any field. A man who can present his subject, no matter how complicated, in simple, logically stated language impresses them and wins points for the program.

The main points to remember about top management are that they are usually logical, direct, action-oriented people. They respect results, not techniques. If they can see a way for the technique to gain the desired results, they will be most impatient to buy whatever the teacher is trying to sell.

Middle Management: A training course for middle management should provide a broad view of the evolution of a product and the precautions that should be taken to prevent the generation of defective material. It should show that the program will do the following:

- Help them do a better job
- Give them more techniques to aid their advancement to higher levels.
- Remove some annoying aspect of their daily existence by defining their specific responsibilities in the quality program
- Help them reduce costs
- Help them meet schedules
- Help them train and control their subordinates
- Make their job more secure

Middle management is populated with people who are usually trying to step up to higher management positions and in some ways exhibit the characteristics of top management personnel. They will be impatient with too technical presentations, but they will understand that in order to reach higher management positions, they must absorb a number of techniques. Symbols, statistics, and formulas can be explored where necessary. But be sure that fine points, sophisticated presentations of conflicts, alternatives, and minutia in general are avoided.

The audience should be given straightforward, understandable tools to apply to their jobs.

Technical and Engineering Staff. A training course for personnel performing duties normally found in a technical and engineering staff should be directed toward the specific needs of this group. Usually, reliability and quality professionals need not participate in these training courses since they normally undergo intensified and continued training in their areas of specialization. The remainder of the staff, especially design engineers, industrial engineers, production engineers, process

engineers, laboratory personnel, and logistic planners, should be provided a comprehensive training course emphasizing:

The technical, scientific, and mathematical philosophies and techniques to solve problems presented

Depending upon the scientific sophistication of the group, the fine points, innuendoes, and alternatives of quality

That the curriculum presented in this quality appreciation course will help them be better staff members and assist them in gaining total system knowledge

Their responsibilities and the steps they should take in fulfilling them

In many instances, technically oriented people complain that they "can't seem to communicate their ideas to management." A part of the training should show the need for simplifying technical ideas when communicating them to management and some methods of communicating with management effectively.

Technical and engineering staff employees will respect the more highly sophisticated technical curriculum. They are interested in the detailed exploration of formulas, proofs, etc. The instructor, however, should spend sufficient time on the organization of the program so that this group will also be aware of the impact of the program on the company and on the individual.

Labor and Clerical Personnel. Despite some opinion to the contrary, training programs for labor and clerical personnel are necessary and serve very useful purposes. Classes for these people should stress:

That the program increases their job security

Ways in which the program may necessitate changes in their jobs (Stress that these changes will benefit rather than hurt them and that they perform a definite part in the program.)

How the program will make their jobs easier

New opportunities the program will provide them

The presentation should be slanted toward motivation, with maximum utilization of Zero Defects. Stress the importance of these individuals to the success of the total effort. Emphasize the areas where they are critical to the completion of the myriad of support activities upon which management depends for success.

In many ways, classes for this group can create a large reservoir of good will for the program if the presentation is properly handled. Most important, do not talk down to the audience.

Class Plans

The following are suggested class plans that can be modified to fit specific situations.

Top Management Course:

- Length of course: 8 hours
- Schedule: 4 hours per day for 2 days
- General Subject Plan:

Program management and individual motivation related to product overall quality	1 hour
Establishment of reliability, maintainability and quality assurance requirements	1 hour
Reliability program elements	2 hours
Maintainability program elements	1 hour
Quality program elements	2 hours
Organization benefits (value, costs, time, etc.)	1 hour
Total	8 hours

Middle Management Course:

- Length of course: 16 hours
- Schedule: 4 hours per day for 4 days

- General Subject Plan:

Program management and individual motivation related to product overall quality	1 hour
Establishment of reliability, maintainability, and quality assurance requirements	1 hour
Reliability program elements	5 hours
Maintainability program elements	2 hours
Quality program elements	5 hours
Integrated program implementation	2 hours
Total	16 hours

Technical and Engineering Staff Course:

- Length of course: 32 hours
- Schedule: 4 hours per day for 8 days
- General subject plan:

Product management related to product overall quality	1 hour
Establishment of reliability, maintainability, and quality assurance requirements	1 hour
Reliability program elements	12 hours
Maintainability program elements	6 hours
Quality program elements	10 hours
Integrated program implementation	2 hours
Total	32 hours

Labor and Clerical Personnel Course:

- Length of course: 6 hours
- Schedule: 2 hours per day for 3 days
- General subject plan:

Need for program, general principles	4 hours
How the program will affect them	2 hours
Total	6 hours

Some General Principles of Training⁶

Training is a method of communication. The teacher is attempting to generate acceptance of ideas, principles, and techniques. Some of the basic principles of this type of communication are listed below:

The basic characteristic of a good teacher is enthusiasm. (It has been said that enthusiasm makes up for a lot of deficiencies in knowledge.) By imparting some of that enthusiasm to his student, the teacher can stimulate him to further study the subject. Fundamentally, most teachers want only to stimulate desire for knowledge.

Good teachers do not attempt to impress their class; they try to influence them to learn.

Good teachers do not complicate a subject by including material the class cannot understand because of inadequate background.

Good teachers realize the capability level of each class and design a course for the average of the group.

The subject matter should not contain language too technical for the group.

All teaching should be designed to determine the self-interest of the group and the subject matter should appeal to this self-interest.

One of the major reasons teachers lose their audience is because they don't know how to say, "I don't know." Too often teachers, when presented with a question they do not understand or for which they have no answer, will try to bluff their way through. Usually the class can detect a bluff and quickly loses respect for the teacher.

Good teachers take advantage of existing aids for training, particularly films prepared by industry. A partial list of films is included in Appendix A.

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DETAILED GUIDE FOR PROGRAM PLANNING

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The purpose of this paper is to present the "What" and "When" aspects of motivation program planning. It delves into the major facets of the plan, from organization and administration, through goal-setting and external/internal interfaces, to awards and promotion.

Initial Program Planning

Development of the motivation program plan requires specific attention to a number of elements:

- Initial program planning and development of top management support
- Establishment of organization responsibilities; selection of the Program Administrator and Motivation Program Council
- Relation of program objectives to time-phased plan, including an operating budget and milestones
- Reduction of defects, including plans for workmanship standards, progress measurement, and challenging goals
- Planning for program support by others, including middle management, unions, suppliers, customers, engineering, manufacturing, planning, etc.
- Development of awards and recognition plans
- Promotional campaign planning, including kickoff meeting plans
- Planning for employee involvement and participation, including individual pledge cards, error identification and suggestions for elimination

Development of Top Management Support

The development of top management support for a Zero Defects type program requires careful definition of the program objectives. The program planner must be certain that they are tailored to fit the

products and services of the organization. Equally important is assurance that the program objectives and progress measurement methods are fully compatible with the people in the plant and with established procedures and systems.

In presenting the ZD program to top management, it must be made clear that no major organizational changes will be required to implement it. Experience indicates that excessive procedure changes, implementation costs, and potential "people problems" result in negative or passive management support.

The ability to utilize current management information systems and to forecast tangible results is of paramount importance. The program planner will at the outset provide his management with some predictions of achievable, measurable (dollar savings) benefits:

- Reduction in rework and scrap
- Improved product yield
- Improved manufacturing direct labor efficiency (percentage realization)
- Reduced product returns and warranty costs
- Reduced re-inspection and retest costs
- Reduced errors in ordering, inventory control, and communication systems

Published reports by many reputable industrial organizations indicate that the annual investment in a well planned motivation program can result in a ten- to forty-fold payoff in cost avoidance and hard savings.

Intangible savings can also result from a well-planned program: reduced absenteeism and tardiness; improved product appearance; increased employee suggestions; improved craftsmanship and pride in product appearance; and significant improvement in customer satisfaction.

The presentation to top management of a simple, time-phased motivation program plan, with clearly outlined potential benefits of the type noted above, can highly motivate top management to proceed with a vigorous, enthusiastic program.

Established methods of measurement and reporting make it easy to secure management approval of evolutionary improvements in systems, procedures, design, manufacturing processes, or other areas, aimed at reducing costs and improving employee morale.

Organization and Administration Planning

Selection of Program Administrator

Since the fundamental duty of the Program Administrator is to provide overall guidance for the program, he must both stimulate and maintain interest at all levels within the organization. As a recognized specialist in internal motivation, he often is called on to describe to a variety of audiences how the program is organized. He is selected for talents as administrator, director, motivator, and salesman. He provides continuing leadership and ensures consistency as he directs the day-to-day functions in the company's Zero Defects program.

To be truly effective, the Program Administrator must give full time to the task. A motivation program is a 52-week-a-year proposition. The actual organizational structure depends, in large part, on the particular organization. However, it is mandatory that the program leadership be high enough in the organization so that the entire company recognizes it as an overall effort. Since a basic tenet of any motivation program is the measurement of defects, the reliability or quality assurance department in many large companies administers the ZD program.

The demands placed upon the program administrator require that he have high character, personality, and individuality—the kind of person who generates respect throughout the company. Longevity is desirable, for often it goes hand-in-hand with respect. He should have a broad range of experience; his regular exposure to the many different areas and levels within the organization require that he be able to speak from authority based on actual working experience. In the final analysis, the most needed qualification is respect, for the "producers" in a company must be motivated by the program administrator.

Since any program of this kind takes a certain amount of salesmanship, the individual who heads up the program must have the basic ability to sell. He needs skill in public presentations—standing before an audience and presenting his thoughts cogently, concisely, and clearly.

The authority vested in the Program Administrator is to develop and maintain a consistent, rewarding program. The stature resulting from his reporting position in the organization provides some impetus, but his basic responsibility is to achieve measurable results. The most successful administrator depends not on vested authority, but on enthusiasm, personal magnetism, and the fundamental understanding of people.

In selecting an individual to administer the motivation program, the company must carefully assess all candidates for the qualifications covered in the preceding paragraphs. The final choice must depend to some degree on the fact that this is a one-time organization. The basic concept of a Zero Defects type program is to "do it right the first time," a phrase that applies to the administrator as well as the worker. The very permanence of the program administrator lends support to his motivational programs throughout the company.

Selection of Plant Motivation Program Council

One of the most important parts of any Zero Defects Program is the Plant Motivation Council, a small group of people who assist the administrator and are an effective extension of his policies. The council assists the administrator in planning and implementing the program. Often ranging from 5 to 10 men, the council contains representatives from engineering, manufacturing, purchasing, industrial relations, finance, quality assurance, tooling, and public relations.

Selling Zero Defects within a company can be enhanced by selecting respected people to make up the council, men who have experience and character. In the Zero Defects concept, if the administrative people are respected, so is the program. Thus, the wise choices for Program Council members are those who have demonstrated their loyalty and abilities through proven performance.

Time-Phased Plan of Action

After the Program Administrator and Program Council have been named, prime goals, schedules, and evaluation processes must be established. One of the first ZD targets should be an area in which success can be achieved quickly, an area with vast improvement potential, one with a relatively high defect rate and high costs. The goals established must be meaningful and reachable for people will believe in a goal only if it is attainable.

There are many ways of establishing goals. One is to use the quality index system which measures and compares mathematically current performance with past performance in those areas where quality control and data statistics on defects and rates are already established. To make the program believable for employees, the goals must be identifiable so that when they are met, the employees can be recognized and rewarded for performance. Enough time should be spent in establishing realistic schedules and target dates so that the objectives can be met. The Program Administrator, with a strong assist from the Program Council, must schedule and establish dates so that the entire Zero Defects effort can be accomplished in an orderly and business-like manner.

The means of providing time evaluation and progress reporting is vitally important to the total effort. A consistent means of charting progress must be a part of the overall plan. The time at which this is done, and in what way, must be understandable to the employee, further emphasizing the importance of believability. At the working level, an evaluation of the program and an evaluation of a particular unit's progress must be provided consistently throughout the organization.

Industry has too often criticized the person who is doing something wrong, while ignoring completely the many people who are doing the job right every day, every time. In a motivation program of this type, a positive approach is an absolute must for its continued success.

Program Budget Planning

The site of the ZD program budget depends upon the particular organization and to what extent it desires to expend its resources. Although the program can be quite economical, it is possible to overspend. Considerable success in motivation can be achieved through recognition, the "pat on the back," the positive approach requiring only sincerity and some dynamic planning.

Advertising is one portion of the program that requires dollar expenditures that must be planned and budgeted by the Program Administrator and the council. Employee interest is stimulated normally through the company newspaper, posters, signs, and so forth. The actual program has other costs. For example, there is a need for an adequate reporting system, some inexpensive tangible rewards for outstanding contributors, and a budget for maintaining the program throughout the year. As an adjunct to this final cost, the program must be laid out over an extended period, considering what motivational needs will occur in the ensuing years as a result of improvement in the defect rates during the current year.

A cost of approximately \$1.50 per employee per year has been experienced in a number of successful programs. Program costs for the first year may be slightly higher, depending on promotional and kickoff ceremony costs. But the real cost of the program must be measured against the cost reduced and final savings reporting. Among the methods commonly used is to place a realistic dollar value on the improved level of quality (reduced rework, scrap, and warranty costs). Therefore, if a company can establish the average cost of a rejection, convert this improved quality to a reduced number of rejections, and multiply that by the average rejection cost, the resulting information will be cost avoidance in terms of dollars and cents, a visible picture of dollars saved to compare with improvement in quality level. These results make the program believable to both the employee and to management. Return on investment has been used as a reference by a number of companies. Ten-to-one returns on invested dollars are not unusual. Some plants have reported auditable savings during early program years of 30:1 over program expenditures.

After the Program Administrator and the council have developed their program plan and budget, it is submitted to senior management for final approval. Assuming that the choice of program administrator was satisfactory, the council was properly selected and personally motivated, and the planning carefully done, the program should sell itself to top management.

Goals and Priorities

Program implementation can only be accomplished if objective program targets have been planned; enough testing has been done to establish that the concept will work within the particular organization; reachable goals have been set; and the schedule for meeting target dates is realistic. Here the Program Council and the Program Administrator must establish at what point in the program development further management approval needs to be secured. Fundamentally, it is reasonable to assume that top management will accept the fact that a carefully planned and budgeted program of this nature can and will be effective.

Finally, in the area of organization and administration, priority for major effort assignment must be set. Although Zero Defects is a company-wide philosophy and attitude, it is reasonable to assume that there are areas within the particular organization that are best suited to start initial program action. It should be established so that the initial areas of concentration are those departments which are operational in nature and, traditionally, have inspection quality control data. This area, however, is only the beginning for an effective Zero Defects program. Zero Defects is a concept that works among all people doing all tasks. It is the kind of program that is as effective for the girl at the typewriter as it is for the man at the engine lathe.

Defect Reduction Planning

For planning defect reduction, first list for each department the probable items that could be considered as goals. The planning activity should commence simultaneously in all departments. All items should be considered that represent the product or performance of the department

whether it be software or hardware. And they should be meaningful so that they represent a real accomplishment when progress is made.

All results should be expressed in quantitative terms. This does not mean only things that can be counted piece by piece. Software products and services (manuals, data, purchase orders, inventory records, etc.) can be measured in terms of objective accomplishment and then reduced to quantitative terms. When groups or individuals are recognized for achievement, those not recognized want to know the criteria used in selecting others.

Achievements should be realistic but not "easy." It is practical to establish two goals for purposes of measurement. The first goal is "zero defects." This does not imply perfect work. Zero Defect work is completion of a task without defects within the quality parameters established. In actuality, this goal is established already. Improvement then becomes the second goal. The measure of improvement must be a flexible target that can be adjusted upward periodically when improvement is made.

Define Workmanship Measurement and Control Plans

A number of methods are available or can be derived to evaluate individuals or groups for defect performance or improvement performance. The computation should be simple enough so that anyone with basic arithmetic knowledge can manipulate the formula. Hard-to-understand or secret methods will create mistrust and result in continuous system changes. Below is a formula used by one company.

Procedure for Comparison of All Departments for the Monthly Zero Defects Award

Definitions:

Department	Departments having a cost center number as assigned by Accounting. Other functions, centers, or units may be eligible as deemed appropriate.
Improvement	The relative position of a department when comparing their "current monthly average" position to the last month position.

Defect Rate	The average defects per hundred hours as it appears on the Quality Performance Visual-Mechanical Defect Report, or an equivalent reference base or standard.
Qualitative Factor	Information applied after evaluation by the Zero Defects Committee which measurably contributes to a department's overall performance. Items for consideration would be meeting production schedules; housekeeping standards; and absenteeism, etc.
Target	The average of the monthly defect rates for rates below the normal average defect rate over a period of 6 months. This target is to be recomputed and applied every 3 months for each department. In the event that the new averages are above the previous 3-month average, the lowest average will be used. Note: A two month average can be used for departments starting in the department award competition.

Policy:

A Zero Defects Committee appointee will accumulate and tabulate necessary Defect Reports, to determine current and improved performance. The tabulated information will be presented to the Zero Defects Committee by the tenth day of each month.

The current standings are determined by the actual numerical position each department is from zero for the month being reported on the Defect Report. All of the departments evaluated will be compared to determine the highest and lowest defect rate. The numerical difference between highest and lowest defect rate will be the range.

Each department's standings will be compared to the range. The department with the lowest defect rate will receive 50 points, and the department with the highest defect rate will receive 0 points.

Formula for computing standings:

Highest defect rate minus lowest defect rate = range

$$\frac{\text{Highest defect rate minus current defect rate} \times 50}{\text{range}} = \text{defect rate points}$$

Improvement is determined by the actual numerical difference for defect rates between the current and previous month on the Defect Report, divided by previous months defect rate to determine percentage improvements.

All of the departments evaluated will be compared to determine the highest and lowest percentage. The numerical difference between will be considered the range. Each department's percent improvement is multiplied by 50 to determine improvement points. Departments increasing in defects will receive zero points.

Formula for computing improvements:

Previous months defect rate minus
current months defect rate = actual improvement

$$\frac{\text{Actual improvement} \times 100}{\text{Previous months defect rate}} = \% \text{ improvement} \times 50 = \text{improvement points}$$

Additional Merit Points will be given thus:

15 points for each week obtaining zero defects

5 points for each week obtaining below target defects

10 points for past three months best average improvement

The sum of the points for defect rate plus improvement plus merit points will determine each department's numerical points.

The Zero Defects Committee will then investigate and apply the Qualitative Factor(s) as deemed appropriate, and subsequently determine the department best representing the goals of the Zero Defects program. Should a department attain Zero Defects for relative standing three months in succession, that department will receive a special merit award.

The formats used in evaluating or registering performance should be designed to reflect progress and status. A progress newsletter, charts in the work areas, and progress reports in the house newspaper are good ways to make progress known.

Good reporting must be directed to all levels of employees. The supervisor should be well informed in details of progress so as to explain it to his subordinates. Further, it is important that all persons are reading the same (related) information.

It is also important that the systems of measurement be endorsed by representatives of management. All progress and status reports should bear signatures of management people who have been associated with the motivation program.

Award and Recognition Plans

Recognition is an integral part of any successful Zero Defects program. If it is meaningful and related to the accomplished task, it serves as a powerful motivating factor. Recognition should be a personal congratulation given to those individuals or groups that, in the opinion of management, have made significant progress toward achieving the program goals.

One requirement of any successful program is having a clear definition of what form the awards will assume at the very beginning. It must be decided if they will have material value or be essentially intangible. It has been proven that personal recognition, as opposed to items of material value, is one of the strongest motivation factors in any program. However, some success has been achieved with items of monetary value.

The employees participating must have a clear understanding of how award recipients will be selected both for individual or group awards. Individual recipients can be selected in several ways: by actual measurement of defect-free performance, by recommendation of his supervisor with subsequent approval by a committee or board, or by recommendation of his peers. It may be necessary to establish different methods in the same company due to differences in actually measuring performance.

Personal recognition, not material reward, has proved to be the strongest long-and-short-term payoff the program can offer. Some successful techniques have included lunch with top plant executives; feature articles on leading achievers in the company newspaper; letters of commendation sent to the employees' homes; special field trips for groups or individuals so that they can see their product in "action"; and pins, plaques, trophies, and scrolls as tangible reminders of individual recognition. Often a simple "thanks" and a pat on the back can be of more value to the employee than a material reward.

Rewards should be planned in sufficient variety for management to select those which will further motivate the particular individual or group involved. Material rewards are considered most effective if they are suitably engraved with the recipient's name and the occasion. For

individuals or individual members of groups, material recognition for achievement is considered appropriate if restricted to low monetary value. Many companies have had success with such items as pen and pencil sets or desk sets as opposed to transistor radios. The idea being that rewards should be decorative or prestige items rather than utilitarian. Cash, stocks, bonds, and other negotiable value awards should be avoided unless the error cause identification portion of the Zero Defects program is tied in with the cash incentive suggestion program. A material reward always should be supplemental to, not in place of, personal recognition by management.

Award ceremonies need to be well planned by the Program Administrator as to time and location and to top management participation. Prior to the ceremony, a comprehensive report giving performance improvement results, reasons for the award, and particularly outstanding achievements should be provided to the management personnel presenting the awards. In addition, arrangements should be made to have photographs taken for publicity purposes. Whenever possible, arrangements should be made to have adjacent or related groups present during the ceremony. This enhances the competitive spirit between groups and gives added impetus to the program.

The Program Administrator must see that all detail preparations, including speeches, presentation aids, etc., are provided for the executive who makes the awards. The quality of the "behind the scenes" preparation is of paramount importance for obvious reasons.

Error-Cause-Removal Planning

The objective of the motivation program is to develop pride in workmanship, personal responsibility and integrity. "Error-Cause-Removal" is a very important part of the program in motivating the individual to direct attention to errors. A sample Error Cause Eliminator form is shown on the following page. The form should include but not be limited to the following:

1. Name of company, corporation, facility and/or division
2. Recognized emblem, motto or name of the motivation program

ERROR CAUSE ELIMINATOR

I BELIEVE THE "ERROR CAUSER" WHICH I AM LISTING IS A POTENTIAL SOURCE OF DEFECTIVE WORKMANSHIP. IF YOU CAN ELIMINATE THIS PROBLEM IT WILL ENHANCE MY CHANCES OF ACHIEVING ERROR-FREE PERFORMANCE IN MY WORK.

NOTE TO THE SUBMITTER: If you have a proposed solution to the problem you think is an "Error Causer" do not use this form. Use an Employee Suggestion Form FW 621.

WHAT IS THE PROBLEM?

HOW DOES THIS PROBLEM CAUSE ERRORS?

		NOT TO BE FILLED IN BY SUBMITTER	
		SUBJECT	
		SUB-TOPIC	
		SERIAL NUMBER	
SUBMITTER		EMPLOYEE NO.	DATE
DEPARTMENT		SHIP	SUPERVISOR
		MAIL YR	MAIL ZONE

3. Simple statement of Error-Cause-Removal use as related to error-free performance
4. Note to submitter differentiating it from the Employee Suggestion form (If the employee has a suggestion for solution, he should submit the suggestion form limiting the use of the Error-Cause-Removal to problems causing errors.)
5. Spaces for submitter's name, number, department, date, and supervisor
6. Spaces for subject and serial number
7. "Mail To" block showing prominently who receives the Error-Cause-Removal

All departments should participate in planning. Coordinators from all departments should be selected in advance and participate in the basic plan. It would perhaps be wise to use the coordinators in the design of the format. Their cooperation and effectiveness will then be a great deal more dependable.

The motivation program attacks the attitude problem in workmanship while the Error-Cause-Removal provides a means of taking care of the physical problems. Like the motivation program, the Error-Cause-Removal requires careful planning and follow-up to make it successful. Its acceptance and use will be directly proportional to employee understanding of the mechanics of its operation and management's attitude and backing. Hence, the supervisor must explain its use in detail. The suggested basic procedure for the Error-Cause-Removal is as follows:

1. Employee identifies on the selected form a known or suspected problem which is causing or could cause errors.
2. First line supervisor checks or verifies that problem exists and corrects if his responsibility.
3. Error-Cause-Removal is submitted to motivation program administrator for correction.
4. Program Administrator submits to responsible department or departments for correction.
5. Program Administrator acknowledges receipt of Error-Cause-Removal to employee and follows up for corrective action.

6. Error is corrected. If not, a detailed explanation must be made causing the employee to feel that it has had appropriate attention. Expeditious handling of the Error-Cause-Removal is of utmost importance to assure the employee that management is interested.

Many suggestions will refer to inadequate lighting, ventilation, space allotment, and general environmental conditions. During the planning phase of the ECR program, it would do well to coordinate with the Chief Plant Engineer and become aware of some of the known or inherent building problems. An overall building update plan may already be in effect or perhaps a long range plan could be developed prior to the implementation of the ECR Plan.

Industrial Engineering will have an important role in the ECR program. Many suggestions will propose changes in design, manufacturing methods, standards of workmanship, office procedures, etc. These suggestions usually will be the most valuable and practical to execute.

Planning for Program Support by Others

If a company's organization is arranged so that top level management reports to a President, then it would be advantageous to request the President to make the first indoctrination presentation to his operating council or to his top level of management. With the known and obvious support of this top level of management, middle management and the first line supervision are more inclined to work toward achieving the goals of the program.

Planning for program support by the various members of middle management can usually be accomplished best by those individuals within the department where the motivation program is used. A person within the department generally understands the departmental problems, how the employees think, and through adequate research can determine the most effective motivation towards achieving certain goals and objectives.

Management and supervision will have the responsibility to implement the program as well as sustaining their organization's interest in the program through propagation of encouragement and reasonable expectations for improvement. They also will have responsibility for reviewing

program results, reporting these results back to top management and for providing recognition for improvements and outstanding performance.

Middle Management and the Supervisor

Middle management indoctrination should include a brief history and background of the Zero Defects program, along with some of the results that have been achieved. It should cite the reasons for the program objectives, such as:

- A program to motivate people to prevent defects caused by human errors
- An organized effort to get people at all levels of the company to do their jobs right the first time, every time, because they want to do the job right
- An attempt to reverse the idea that to err is human by appealing to the pride of people in avoiding errors completely
- A program that can be applied to all activities in the company
- Voluntary enlistment in a program to improve quality and reduce cost

The presentation should cover some of the assessments of opportunities found by the task team that leads them to believe the company should have the program. And, finally, the indoctrination should outline the actions to be taken to implement the program in the supervisors' areas of responsibility.

Plans for implementing the program down to the grass roots should be detailed. Time schedules should be coordinated with existing program plans. Methods of measuring progress should be developed and coordinated with concerned middle management so they may be assured of fairness and no duplication of effort.

Planning for supervisory indoctrination should always keep foremost the idea of motivation. Motivation can be most effectively carried out at the departmental level. Therefore, planning should not only familiarize the supervisor with the basic goals, but also should be functionally designed to assist his department achieve them. Departmental goals should

be established by the individual departments because employees can more closely identify themselves with goals they help set. Of course, these departmental goals should coincide with the goals established for the company.

Indoctrination of the first-line supervisor should carry the thought that the ZD program will help him do his job. It will be that much easier if his subordinates are personally motivated to do good work; and if the supervisor can progressively give more attention to his own assigned tasks commensurate with the reduction in errors by upstream departments.

Supervisor indoctrination also should remind him of how to motivate employees to attain set goals and how the appeal may be effectively presented. Since we have already told him why we have the program, and what the program is, we also need to further advise the supervisor on how he should use the program, and what it will do for him and the company.

Prior to formal indoctrinations, the motivation program should have been widely advertised to make every employee aware of the importance the company attaches to fine workmanship. The supervisor, then, can use the motivation program as a backup tool to influence his subordinates to improve their performance.

To build good workmanship at the grass roots, a supervisor must develop a cooperative person-to-person relationship by:

Telling the employees, in personal contacts, why we have the motivation program

Telling the employees the objectives of the program so they understand it as well as we do

Giving employees specific goals which are steps in achieving the objectives (Make them short-ranged and something within their reach.)

Making employees feel they are on the team and are a part of the program

Getting employees to do the job right because they want to do it right

Preventing errors is more beneficial than correcting errors after they happen. To prevent errors, it is essential to identify the cause of errors. Some preventive measures:

Making a checklist of potential defects or errors — critical errors, major errors and minor errors

Tallying defects on the checklists, perhaps daily, to identify those which are most important and most frequent

Checking defects back to their source, preferably to the person responsible for them

Talking to employees about defects and soliciting their suggestions on causes and remedies

Consulting specialists who can assist in identifying the cause of defects

It would be valuable to have an analysis of every job that shows sequence of operations and identifies the key steps which are critical to error-free work, or the danger points where errors and defects are apt to occur. At these danger points, it would be helpful to describe the technique or "tricks of the trade" which are essential to doing the job properly. There may be a need to ascertain employee skills. Has he done the work before? Did the same standards apply then as now? What new techniques does he need to know? Perhaps we need to tell him how to do critical key steps. Show him how. Have him do it. Watch him do it. Correct his mistake. We need to encourage the employee to ask questions before he makes a mistake.

A supervisor must inform the employee that quality has to be built into a product and through a process of self-inspection, make sure he does it right. The employee must know what is expected of him, what tolerances and control limits are acceptable. Employees need to be encouraged to report defects at the time they are made so future errors may be prevented.

Planning for Union Participation

The labor union must be brought into the motivation program before any commitment is made public. Management should have already made the decision to adopt the program. Complete program orientation should

then be made to several of the union representatives in the presence of high-level company officials. Normally, little opposition is made by the union if they are made to understand that the program is aimed at bringing out the best in an individual.

Union representation should be a functional and active part of the early planning activity. A shop steward or equivalent should be a member of the Motivation Program Council. Union representatives will usually have good suggestions as to the types of recognition that will not conflict with union policies. Special indoctrination meetings with union stewards may be desirable to brief them on the philosophy, the benefits, and the concepts of the program.

Where a special kickoff day ceremony is planned, consideration should be given to inviting one of the union officials to speak on the union's participation in the program. A special participation award should be presented to the union for its cooperation in the entire program.

Engineering Participation

Product quality is enhanced by engineering in many ways, including the avoidance of drawing errors, clarity and timeliness of critical design information, design aspects of manufacturing feasibility, functional simplicity, and ease of testing. Program emphasis on Zero Defects in the end product translates into "error elimination" in the manufacturing process. In activities more removed from the production line (e. g., engineering), it translates into a complex of factors of which error elimination is but one. To the extent feasible, each contributing factor should receive attention within the framework of a Zero Defects motivation program. It is both inadequate and discriminatory to focus program attention on error elimination to the exclusion of the many other factors that contribute to a defect-free product.

Exactness is a characteristic of engineering. Yet engineering practice entails the taking of calculated risks to the extent that there must be reliance on subjective judgment. Such reliance tends to be greater

in situations characterized by changing technology, competitive pressures and customer demand. These work situations are the rule rather than the exception within the defense industry. An adequate evaluation of the quality or correctness of engineering output in such situations can seldom be done on a purely objective basis.

Business organizations reserve to themselves the right to establish and to apply quality standards for end products, but defer to the organized professions the prerogative for maintaining and administering quality standards for professional work.

Engineering is a profession. An engineer may belong to one or more of the many technical groups within the engineering profession. Each group member tends to see all other members as his professional equals or peers regardless of their organizational standing. Each peer group determines and maintains its standards of professional practice, judges the significance of the technical accomplishments of its members, and provides understanding, support and recognition that only they can furnish. The engineer looks to his peer group for the recognition of accomplishments and for the understanding that only it can provide.

Both pride and loyalty characterize the engineer. Loyalty to his profession, however, is often stronger than loyalty to his employer. Judgment of the quality of his technical performance by his peers tends to be most meaningful.

The above observations have implications for the Zero Defects program planner striving to elicit engineering support.

Toward what objectives may engineering personnel strive in making their contribution to a defect-free product? A list of objectives for the engineering function includes items that directly, as well as indirectly, affect product quality:

1. Substantive accuracy of design drawings and information
2. Clarity, substantive completeness and timeliness of engineering information
3. Producibility of design
4. Functional and operational quality and maintainability within contractual requirements

5. Completion of work within cost and schedule targets
6. Creative expression in design
7. Development of professional abilities

An engineering activity that contributes to the achievement of any of these or similarly oriented objectives is eligible provided there exists a meaningful way to measure the degree of achievement. An objective determination is most desirable, but this is not always possible without loss of meaning to those interpreting or using the data. Subjective determination of achievement is quite appropriate if it results in an unequivocal basis for motivating improvement in output quality.

Among the early Zero Defects programs attempted within the engineering department, emphasis was sometimes concentrated on drawing accuracy because of its obvious impact on the end product. The exclusive focus on drawing errors tended to be viewed as discrimination in favor of the large proportion of engineers who did not produce drawings. Efforts to focus on the wide variety of errors made by engineers regardless of the kind of work they performed, tended to be viewed by them as a preoccupation with trivia not related to a defect-free end product. Although equal emphasis cannot be given to each of the engineering objectives listed, they should all be considered if the degree of achievement can be meaningfully evaluated.

An effective appeal for program support by engineering personnel must recognize the motivational significance of professional pride. An alternative appeal to "error-free work" or "quality output" leaves much to be desired and should not be presumed motivational — it may even inhibit proper motivation.

A professional tends to perceive as authoritative an evaluation consistent with professional standards, based on personally accepted goals, recognizing the particular subjective nature of his work, and performed by a professional peer. Even an evaluation made by an organizational superior will tend to be rejected if the superior is not an acknowledged peer.

Output quality should be evaluated for an organization as a whole, where the smallest item of work appropriate for evaluation involves more than one individual. "Appropriate" means large enough to provide a meaningful appraisal to the workers involved and to avoid excessive appraisal activity. "Appropriate" also could mean small enough to ensure statistic stability of the number of work items occurring within successive evaluation periods. It is expected that most evaluation will be done for engineering groups, but a special effort should be made to find bases for recognizing individual performance. Some of the more useful indicators for evaluating individual performance quality will be found in the areas of creative expression and professional development.

Recognition, too, should be extended to organizational units as well as individuals. In either case, the considerations are the same. Recognition based on a valid appraisal of accomplishment and bestowed by a professional peer of superior standing within the organization will carry with it a greater motivational effect.

Obtaining program support from engineering personnel must finally depend on the sensitivity of program administrators to the needs in each situation and their ability to adapt the program to these needs. Such adaptations are discussed below.

Kickoff Plans. Publicity and promotion literature must be prepared for making a professional-level appeal. Briefings must be conducted on a professional plane.

Pledge Cards and Pins. Pledge cards should not be used among professional personnel. It must be presumed that all engineers have dedicated themselves to the high standards maintained by their professional peer group. A pin suitable for business wear may be found acceptable as an outward manifestation of personal commitment to a motivation program, but its acceptance and display should not be sought as an indication of commitment to professional standards.

Quality Measurement Parameters and Methods. The indicators of engineering output quality and the methods for computing quality must be jointly determined by program administrators and representative members of that unit. Compromises made for the sake of uniformity among

departments should be held to a minimum; self-motivation is a far more important objective than is a broad, homogeneous base for evaluation. Concentrate on a very limited number of quality indicators at any one time. Change an indicator when the point of diminishing returns is approached.

Goals for Improvement. Individual goals should be set by the individual; group goals should be set by consensus. Goal setting begins with knowledge of the expectations and prior commitments of the superior. At each level, a suitable commitment should be made with full knowledge of the superior's expectations.

Record Keeping. Brief, easily kept records will tend to ensure good record keeping. Records may be kept by the supervisor of an organizational unit, by an administrative assistant, or by others if the supervisor knows he retains control over their interpretation.

Appraisal of Output Quality. It must be the supervisor's prerogative to interpret the data recorded for his group and to express quality of output for each selected indicator. To appraise individual performance the supervisor should rely on group opinion, unless the group desires that he be the judge. Appraisals performed outside the group, even with group sanction, should not be expected to engender the climate for effective self-motivation.

Progress Reporting and Evaluation. Group supervisor should submit his (and his group's) appraisal of group and individual performance quality, including recommendations for recognition. The evaluation of these reports and the selection of winners may be handled within the line organization or by motivation program committees.

Feedback of Results. Prompt feedback of results from group and supervisory appraisals should be made to let group members know how they are doing and to provide the basis for setting new goals. A chart display of results may prove useful as a reminder of new goals and the effort needed to achieve them. It may also have utility for inspiring competition.

Types of Recognition. Recognition is warranted for all personnel in accordance with the results of appraisals. Inadequate achievers should receive help and encouragement. Adequate achievers should be informed of their good work and discretely encouraged to demonstrate their potential. Outstanding achievers should receive awards and commendations accompanied by publicity.

Commendations and Awards. Recognition by commendation or award should be bestowed by a person of high standing within the organization — if possible, one who is also a professional peer. When awards are in order, they should be in keeping with professional taste; e. g., tie-tack, pen, book, zipper brief, framed picture, luncheon with the chief engineer, theater tickets, etc. In some situations, a letter or a certificate of merit may be appropriate to confirm a commendation. Circulating trophies or plaques may be used when citing a group for its achievement.

The appeal for professionalism and growth must be accompanied by encouragement of professional society membership and activity; membership on technical working committees; professional registration; and continuing education and development. This appeal can be furthered by providing opportunities and financial support for these activities.

Supplier Program Planning

Many organizations purchase a significant amount of material, equipment, or services, the quality of which directly affects total program costs and employee morale. A supplier motivation program can be of real value.

Prior to any approach to the supplier organizations, however, it is essential that the exact methods of evaluation and measurement be established. In most cases measurement of supplier Zero Defect programs can be accomplished through such already established systems as supplier performance indices, receiving inspection records, past performance records or simply through a combination of cost, schedule and quality goals. However, the specific criteria for recognition must be clearly defined and most properly should be carried out by the Zero Defects Administrator with approval by the council and top management.

Briefings can then be held with supplier officials to explain the purpose of the Zero Defects Program and to solicit their participation. These briefings can assume several forms, including participation in massive "Kickoff Day" ceremonies at the prime contractor's plant (with participation by top officials of the company, and with the presidents and/or general managers of all supplier companies in attendance); briefings of smaller supplier executive groups (based on similar products produced); or briefings of groups based on company size. Regardless of the type of briefings used, it is imperative that top management be a part of meetings representing the purchaser, the suppliers, and the final customers (users), where feasible.

During these briefings, the goals of the program, the criteria used for measurement and the methods of recognition should be thoroughly reviewed. It is also highly recommended that the smaller briefings be utilized for workshop type sessions to explore Zero Defects programming concepts and practices. These can be used very effectively in giving assistance in actual program planning.

A key portion of the supplier participation program is recognition or awards. It is important that supplier performance achievements be recognized whenever possible. Such recognition can easily take the form of a plaque or framed certificate presented to the supplier by top management. In addition, it is good practice to display an "Honor Roll of Zero Defects Suppliers" where it can be seen by visitors to the company and other suppliers.

Every effort should be made to assure that the supplier being recognized receives "external" publicity, particularly in his own locale. Press release distribution to the local newspapers and other news media is a standard technique. Quite often the contractor's own public relations staff can help make arrangements in advance of the actual award presentation. In all cases, the supplier himself should be requested to participate in these arrangements, or if he cares to do so, actually make them himself. His company is being recognized and he knows best which type of publicity is most effective.

Performance quality indicators that may be used in the evaluation should be determined within the framework of the engineering program objectives previously listed. Where a direct measure of output quality is not feasible, recourse may be made to secondary measures. However, care should be taken to avoid the use of trivial indicators. The table below presents some examples of acceptable indicators and suggested units of measure for each. The importance of using positive units of measure should not be underestimated.

<u>Indicators of Quality</u>	<u>Units of Measure</u>
Accuracy of drawings, repetitive reports and documents	Number of items or square feet of drawings completed without error ¹ Number of drawings completed without formal change due to engineering error Number of documents issued without subsequent revision due to error Number of errors-per-unit-output
Success of qualification tests	Number completed or hours duration without need for rerun Number of test discrepancies
Completion of discrete tasks ²	Number completed without subsequent revision due to error ³ Number completed within schedule targets Number completed within cost targets
Design review results	Number of discrepancies per 1000 manhours of input
Achievement of design improvement targets ⁴	Percent of target value
Error cause identification	Number of causes identified per person Number of causes eliminated per person
Creative expression	Number of patents received ⁵ Number of technical papers published or presented ⁵ A single outstanding concept or solution
Professional development ⁵	Professional society membership Professional society participation Number of technical courses taken

¹Errors should be confined to mistakes of omission or commission that could have an impact on costs or schedule or could cause a customer to receive an undesirable product.

²Tasks may be of random size but the ratio of the extremes of the range of sizes should not be too great. Number of task completions within a period should be great enough to provide statistical stability over time.

³In this instance, error should be interpreted as any combination of mistakes (in the delivered product of a task) that could cause a downstream group unnecessary labor or schedule slippage or cause a customer to receive an undesirable product. Errors found prior to delivery should not be counted, per se, because their impact is reflected in the performing group's cost and schedule record.

⁴Targets may be quantitative goals for weight, reliability, maintenance time, end item cost, etc.

⁵Use of this item should be accompanied by activities to encourage and facilitate employee action.

It is often quite effective, particularly in the case of small suppliers, to have the presentation made before the entire work force at a lunch hour or some other suitable time. This serves to recognize all employees who contributed to the award.

Promotional Campaign Planning

The initial promotional campaign may be divided into three phases: supervisory indoctrination; pre-implementation promotion; and employee indoctrination. The promotional campaign should be carefully scheduled, with sufficient time allowed to carry out each of its three phases. Illustrative and other printed material, such as posters, supervisors and employees handbooks, banners, and signs, should be designed and ready for distribution early in the schedule. A program symbol or "trademark" helps identify the program and may be used extensively program materials. The public relations office or outside consultants are often used to help give professional promotional know-how to the campaign.

Phase 1, supervisory indoctrination and training, is of prime importance to the campaign. Supervision must be sold on the fact that the Zero Defects program is a management tool, and should be used as such to realize its potential benefits. A supervisor's handbook has proved to be a valuable aid. The handbook fully explains the purpose, methods, scope and sequence of the program and should give the supervisor a clear understanding of what is expected of him.

Also during Phase 1, local labor union support should be solicited. The real goal of the program is in consonance with many union goals and the philosophy is in accord with responsible union objectives. Given the opportunity to participate actively, unions have proved to be enthusiastic supporters of Zero Defects programming.

Phase 2 of the promotional campaign consists essentially of program buildup and is designed to create the proper environment for the "kick-off" of the program. Its purpose is to develop general interest and curiosity. The program symbol is first introduced at this point and is supplemented with posters, banners, and other "teaser" materials. The

posters and banners can be designed so that a little more information may be introduced each day until the program is completely revealed.

Phase 3, employee indoctrination, tells everyone what the program is all about. It begins with the kickoff meeting when all employees are asked to support the program. Preparations for the kickoff may include putting up (during the night) banners at all employee gates daying, "Zero Defects Is Here, " and placing posters on all bulletin boards posters stressing:

Do It Right the First Time

Check Your Work

Strive for Perfection

Have Pride in Your Work

The amount of public relations work done outside the plant through local news media will be determined by the size of the community in which a plant is located. Obviously, a small community can take a greater interest in some of the awards and recognition activities. Since most plants are in larger cities where newsworthy items are more selective, it is important to save your contacts for the big activities and then try to get as much interest as the traffic will bear. Probably two or three well planned activities throughout the year would tend to get better and more effective news coverage. Recognition to the company by defense customers is usually acceptable news and wide publicity is encouraged. Company-wide activities marking certain milestones in the motivation program are always good publicity items to build up to.

The most common and, by necessity, the most practical in-plant motivational techniques are the house organ and posters. The great difficulty here is the search for originality. Campaigns for employee submittal of poster or slogan ideas are often good and provide an excellent added motivational stimulus. Letters to the individual's home from the head of the company are good for some recognition and motivation purposes but too many letters of this type tend to weaken the impact. Further, it is difficult to relay a personal feeling in a mass-produced letter, no matter how well chosen the words.

The Kickoff Meeting

The kickoff, following the planned teaser campaign would be preceded immediately with wide publicity indicating that something very special will occur on a specific date and time. If possible, it is considered effective to schedule the kickoff to coincide with another important event such as receipt of a new contract, outstanding performance citation, or a particular noteworthy achievement.

This meeting is usually divided into two phases: the plant-wide meeting, followed by a meeting by the supervisor and his people. In the plant-wide meeting, management explains the challenge of the motivation program and importance of every employee supporting the program. The supervisor and employee meeting should follow immediately, not later than the following day. This takes advantage of the enthusiasm and impact generated the day before and provide a less formal environment for answering questions.

Careful planning should go into the selection of a meeting place for the kickoff. If possible, in-plant facilities should be used as they are more convenient and less time will be lost. However, if the use of plant facilities creates problems such as noise, lack of a suitable meeting place, or security arrangements, an out-of-plant location should be arranged. Employees should not be asked to attend on their own time.

Planning for the kickoff meeting should be completed far enough in advance of the intended date so that the presence of important guests and speakers can be assured. Industry, Government, union and community leaders are often included on the guest list. The role of the Zero Defects Program Administrator, in addition to coordinating arrangements and schedules, acts as master of ceremonies and as host of the event. It is highly desirable that top company and plant executives be active participants in the meeting.

The employee's role in the company and the importance of competitive economics as it relates to the individual employee should be stressed. If possible, representatives of local employee bargaining units should be encouraged to participate. Their part should be to stress the job security

benefits of Zero Defects programs. A major customer's representative often is asked to speak to the employees about individual effort as it is related to the final product.

Usually, as a part of the kickoff meeting, all employees are asked to sign a pledge stating that they will strive for the attainment of quality workmanship. Some programs use a small, wallet size pledge card, which is returned to the employee. Other programs have used a small card with the pledge on one side and a calendar or other useful information on the other. Also, an enlargement of the pledge card is usually displayed permanently in the employee's department or work area. Identification, such as special pins or badges, should be given to employees who sign the pledge.

The various phases presented here are by no means the only approach to Zero Defects promotional planning. Each company or organization differs in its own particular operating and management environment. Many programs experience difficulty in the second and third years through loss of vitality, employee appeal, and results. It is important to plan and develop program enthusiasm and support at all levels on a logical and economic basis. Reiterative review of plans and results achieved is needed in order to improve or retain the needed results.

Motivation Program Planning Checklist

A. Initial Program Planning

1. Development of Top Management support of program objectives

B. Organization and Administration

1. Selection of Program Administrator

Define basic duties
Reporting position in organization
Qualification requirements—define clearly
Define authority and basic responsibilities
Screen candidates—select individual

2. Selection of Plant Motivation Program Council

Objective: Assist Administrator in planning and implementing program

Membership: Representatives of all key departments and functions in plant—five to ten men

Typical functions represented are:

Design	Quality Assurance
Manufacturing	Tooling
Purchasing	Industrial Relations
Finance	Public Relations

3. Relate Program Objectives to Time-Phased Plan of Action

Identify prime targets based on defect rates and costs
Establish goals, in numerical terms
Set schedules and target dates
Provide for timely evaluation and reporting of progress
Assure positive (not critical) recognition for good work

4. Program Budget Planning

Develop program initiation costs
Provide program continuation cost estimates
Develop cost reduction estimates and final savings report format
Secure management approval

5. Set Priorities—Based on Defect Rates and Costs

Plan for major effort assignments
Allocate resources on planned priority basis

Department—Shops
Processes—Products
Services

C. Defect Reduction Planning

1. Set Departmental Goals for Defect Reduction

Based on cost of scrap and rework, or
Percentage, or other numeric basis
Make solid achievement a requisite
Express results in quantitative terms

2. Define Workmanship Measurement and Control Plans

Provide simple score-keeping plan
Progress reporting—by organization element
Two-way communications—Management=Employee
Assure management support and direction

3. Error Cause Removal Planning

This planning must be complete before program kickoff
Define methods for probing and removal of errors in advance
Tie in employee suggestion program and cash awards
Coordinate plans with supervision
Plan initial work environment improvements such as:

Lighting, ventilation, work benches, etc.

Plan for improved visual aids and standards of workmanship
Identify employee with important completed tasks

4. Planning for Group Performance Goals

For Quality Improvement

Product-oriented employees
Services-oriented employees—office work, design, etc.

For Cost Improvement

Cost reduction
Cost avoidance

D. Planning for Program Support by Others

1. Middle Management and the Supervisor

- Indoctrination program planning
- Top management briefings and endorsement
- Middle management indoctrination and suggestion solicitation
- Supervisor (foreman) indoctrination and suggestion solicitation

2. Planning for Union Participation and Support

- Define advantages to the union
- Role in planning of the program
- Role during initiation ceremony
- Role in conduct of the program

3. Design Improvement Planning

Relate program objectives to:

- Individual improvement, skills, knowledge
- Improved designs, reliability, manufacturing cost, performance
- Improved morale and personnel performance

Establish advance plans for:

- Facilities and environment study and improvement in lighting, ventilation, arrangement, etc.
- Training, professional society participation

Establishment of parameters for measurement and competition

Design program kickoff plans:

Publicity	Formal Sessions
Promotion	Individual Communication
Briefings	

Individual and group awards and presentations

Recognition of exceptional achievements:

- Technical results
- Responsibility acceptance
- Creativity—patents
- Papers published

Design review results

Training, broad spectrum, specific subjects for individual

Human factors and value engineering design reviews

4. Improved Manufacturing Planning

- Tooling, machines, jigs, manufacturing aids
- Materials, improved, traceability improvements
- Processes, controls, identification

5. Supplier Program Planning

Plan the Evaluation and Measurement Methods:

Quality, schedule, cost

Plan briefings of supplier officials

Devise awards and presentation ceremonies

Provide favorable publicity and competitive conditions

E. Award and Recognition Plans for Top Management

1. Define nature of awards

2. Provide clear description of award selection process:

Individual employees

Employee groups

3. Provide for variety of awards:

Recognition awards by top management—plaques—certificates

Supplemental (prize) awards:

Jewelry, appliances, trading stamps, cash

Bonds, company stock—others

4. Arrange Format of Award Ceremonies and Publicity

Provide staff work for top management presentation of awards

Encourage increasing departmental competition through
award ceremonies

F. Promotional Campaign Planning

1. Define basic program phase requirements and schedules

2. Determine and provide examples of motivational methods
and techniques

3. Provide public relations assistance and know-how on:

Creating initial interest—promotional phase

Main motivational public relations techniques

Award ceremonies

Television briefings, news articles, posters

Letters to individual homes by plant managers, etc.

4. Planning the Kickoff Meeting

Selection of meeting place

In-plant facilities—advantages and disadvantages

Out-of-plant facilities—advantages and disadvantages.

The participants and roles in the kickoff meeting:

- Top company executive
- Top plant executive
- Local plant manager
- Union representative
- Major customers' representatives
- Major suppliers' representatives
- Motivation program administrator

5. Planning for Use of Employee Pledge Cards

- Devise cards and implement use of same
- Award pledge pins in appropriate fashion
- Award (100% pledge) group posters to applicable departments
- Instill group competition spirit through progressive programs

6. Planning for Motivation Material Kits

Describe types of items, and illustrate examples:

- Employee's handbook, pledge card, error/excess identification forms

Outline practical methods of distribution

Describe sustaining program motivation material kit plans and techniques

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SUSTAINING THE ZD PROGRAM

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The purpose of this paper is to suggest specific actions to be taken to ensure that a quality motivation program, once established, will be sustained and retain its viability. The actions to be discussed fall under the headings, "Planning," "Pulsing," and "Procedurizing."

Planning is self-explanatory. Pulsing pertains to those actions that are synchronized with anticipated needs and with anticipated periods of program acceleration and deceleration. Procedurizing pertains to packaging these actions to be used as ready reference in any facet of the program. Collectively then, to plan, pulse, and prepare procedures sustains a Zero Defects program over a long period of time.

Planning

Planning a quality motivation program requires the establishment of definite objectives and the outlining of actions to ensure the successful conclusion of these objectives, i. e.:

- To motivate each individual to want to perform his job right the first time
- To identify the performance to be measured
- To take action to increase error-free performance
- To measure progress toward error-free performance
- To recognize individuals' and groups' Zero Defects performance

Generally, responsibility for implementing the plans is delegated to various types of councils, such as publicity, communication, data measurement and awards. Early creation of these councils will provide an excellent means for obtaining employee participation on a large scale. Management and nonmanagement orientation pamphlets or booklets have to be planned early to help people understand the program. Planning also includes the dissemination of information to union officials, stewards,

and committeemen. The symbol for the program should be developed for use on pins, decals, letterheads and other documentation. A campaign to provide continuous employee stimulation should also be planned at this time. Because the success of the Zero Defects program is wholly dependent on the reaction and acceptance of the people, careful planning of the sustaining portion of the program is extremely important.

An effective publicity campaign should take advantage of readily available in-house communication media. A portion of the Zero Defects budget should be earmarked for other forms of publicity.

Also important is recognition for individuals, groups, sections, departments, and divisions so that the working entity is wholly encompassed by the awards plan.

Employee Advisory Councils

Employee advisory councils, made up separately of nonmanagement and management personnel throughout the company, are effective in perpetuating a Zero Defects program. The councils, which should be limited to no more than ten or twelve people each, provide a forum for discussing:

- Ways to promote the most effective participation by the greatest number of people
- Weak and strong points of the program
- Ways to sustain the program
- Which awards are most popular, and which methods of presentation are preferred
- Ways to celebrate or recognize yearly anniversaries
- Open discussion on any phase or part of the program

Council membership should be rotated. This scheme sets the stage for fresh ideas and new perspectives, which are multiplicative in their contribution to the program. The councils should meet frequently, on the average of one hour per week.

The advisory council approach for sustaining a ZD program has many advantages. Each employee has a voice in the administration of the program. Personal involvement helps the employee realize that

not only does he benefit from his own error-free work, but he is also instrumental in steering the ZD program on an efficient and meaningful course.

Error Cause Identification and Removal

At the top of any list of ideas for sustaining a ZD program is the means for identifying and taking expedient remedial action to remove error causes. There are some errors over which the employee has little control. For example: a tool or machine that won't hold the required tolerance; material that does not meet specification; or improper shipping methods which bend, twist, or scratch materials or parts. However, the employee can be encouraged to bring the deficiency to the attention of those who can take corrective action.

The error cause identification (ECI) facet of the program is a continuing effort to encourage every employee to work toward perfection. Error causes are identified and eliminated with a resultant downward trend in errors. Because every employee is urged to participate in the ECI plan, their continuing support to the overall program has considerable impact.

Pulsing

Just as the heart needs rest to keep the body functioning, so must the constant pounding for ZD be slowed or muffled periodically if program longevity is to be realized. This means that the sustaining effort will have planned peaks of highly visible activity and valleys of public inactivity. In other words, the program pulses.

The ZD administrator must not allow himself to explode in all directions. He must exercise control over the plans to sustain interest and action so that the effort is not too much for too long, or it will burn itself—and the administrator—out at an early age.

Peaks and valleys—the pulsings—should be obvious through varying emphasis on different aspects of the effort used in maintaining interest and active participation in the program. Peaks may be represented by a competition between organizations by shift, numbers of produced articles, or numbers of hours with no rejects. A contest for a slogan or a

crossword puzzle, might attract attention. Valleys, periods of relative calm, should be interspersed between peaks; normal maintenance of the program continues but no great emphasis is placed on publicity or special promotional activities.

House Organs

Headlines in company publications such as "ZD MAN OF THE MONTH HONORED AT LUNCHEON" or "ELECTRIC SHOP HARNESS GROUP PRODUCES 110 COMPLEX ASSEMBLIES ERROR FREE" do much to engender friendly competition among employees. Most people want to be recognized for excellence in their job. When people are recognized through the company paper or bulletin board announcements, they know that their efforts are appreciated. The public record of achievements encourages employees to do their utmost and instills interest and desire in expending the additional effort required for recognition. This type of sustaining effort also is well adapted to publicize program trends on the broad scale or to announce forthcoming events to pique the highest possible interest.

Contests

Inexpensive and appealing promotional contests range from writing slogans or poems to designing posters or crossword puzzles. In this approach, opportunity to participate and be recognized is given an employee who might not have this chance on his job assignment.

Communications and Publicity

The success of a Zero Defects program will depend largely on stimulating and maintaining interest and support at all levels of the company. Primary factors involved in this task include communication and publicity. Both means for disseminating information can be used to arouse interest and solicit participation, as well as serve as feedback loops to inform employees of program status and success.

One method to arouse individual interest is, of course, publicizing awards. Displays in strategic locations can include both names and photographs of award recipients. Display panels can be effective also to illustrate acceptable versus nonacceptable work, to show membership in ZD clubs, and to chart error trends.

The company newspaper, again, can publish articles by selected employees on the subject, "What Zero Defects Means to Me." Stories on awards and accomplishments, along with winning slogans, poems and crossword puzzles, can also be included in the newspaper. Outstanding contributions to the program can be recognized by devoting space for photos of contributors and descriptions of their suggestions.

The public address system is highly useful to announce significant events or outstanding employee performance. ZD anniversary parties are also effective in sustaining interest in the program.

The Zero Defects emblem on decals, stationery, posters, and awards has high publicity impact. The use of tags or rubber stamps bearing an emblem on shipments or on inspection tags of defect-free parts is also effective. It is most important that the results of the program are clearly visible for all to see. Posted charts indicating goals and progress toward error-free performance should be in full view in all areas where people work or congregate. Occasionally, a special report should be published which provides a summary of the total effort.

Aids to Momentum

The major aids to program momentum stem from efforts by the program administrator to gain new knowledge and ideas. The administrator should attend and/or conduct seminars whenever possible to promote the free exchange of program improvement ideas between companies or agencies. He should also endeavor to visit other participating agencies or companies to cross-fertilize ideas. On the same line, he should invite others to visit his company or agency.

Setting up a supplier award program and informing employees of this outside participation is useful in maintaining program momentum. "Think" sessions between management and/or nonmanagement personnel can also result in momentum-stimulating concepts.

Animated displays of ZD at work spark interest and enthusiasm in employees and point up the importance of following directions.

Procedurizing

Clarity of purpose and consistency of action are goals which must be reached soon after the challenge of Zero Defects is accepted. Administrative procedures and operating instructions which define management support and direct the logistics of the program provide the roots for healthy and continued growth. When there is understanding of the job to be done and directions as to how to do it, the objectives are usually met.

Each employee council should have a basic charter which will clearly identify what it is supposed to do, who its members are, and how the members are selected, as well as a general outline of meeting schedules. Once this is done and the information distributed, communications links will have been established that will help sustain the program simply by the elimination of confusion.

Awards Plan

Personal recognition is important to sustain employee interest. For some companies, awards are of equal consequence.

Awards plans differ according to the factors involved in the program. Administrators have to consider budget limitations, numbers and ages of employees, types of work involved and other salient considerations. The awards themselves can range from an inexpensive ball point pen or a box of golf balls, to a handsome wrist watch or television set, each imprinted with the local ZD identification.

The awards plan adds immeasurably to the sustaining effort because individuals receive a physical token of appreciation. Program identification pins are worn with pride; they are particularly advantageous in that the material used, i.e., silver, gold, or jewels, can indicate the type of award. Pen and pencil desk sets are prominently displayed. Certificates are framed and exhibited. Each award is proof that the individual is appreciated for his efforts and active participation in support of the program. When one employee sees another's well-earned recognition, he, too, wants to be recognized. His interest is thus sustained in the program. Both he and the company or agency gain because of his desire to excel and be recognized as a ZD performer.

Staff Meetings

A valuable line of communication among management and nonmanagement employees is the staff meeting. It provides an excellent opportunity for the Zero Defects administrator to give a synopsis of the program and to keep most employees up to date on the latest happenings, significant events, and future plans. This action maintains high-level interest and becomes a stable part of the agency or company operation.

Insuring Program Continuity

Novel approaches and stimulating events may manifest themselves during program duration, but five primary factors are fundamental to assuring individual participation and interest.

- Indoctrination and education
- Communications and publicity
- Recognition and awards
- Aids to momentum
- Renewal of impetus

A significant factor in determining employee interest and participation is the maintenance of a dynamic indoctrination and education program. It will not only result in a high level of program awareness, but also will encourage participation by showing each individual the benefits that his organization can derive from the ZD program.

Indoctrination and education programs can be carried out informally. A description of the ZD program should be incorporated into new-employee indoctrination procedures. During this indoctrination, each new employee should be encouraged to subscribe to the ZD philosophy. When the employee reports to his work area, he should be encouraged to sign the pledge scroll pertaining to his group.

Following indoctrination, each employee should be informed about the interrelationship of his assignment to other operations, processes, systems, installations, procedures, etc. They will thus realize the importance of each task in meeting the overall company objective. Movies can

be shown periodically to explain Zero Defects and its importance. Common mistakes relative to particular tasks can be brought out as publicized. Informal crew meetings conducted periodically on all shifts by first-line supervisors can act as a forum for discussing Zero Defects items and accomplishments.

In planning recognition and award campaigns, both group and individual recognition and awards must be considered. Group recognition and awards serve two major functions: they instill pride in group participation and they engender healthy competition between groups with interrelated functions. Individual recognition and awards convey professional prestige to the winner, serve to motivate other individuals, and are instrumental in fostering realization of the importance each individual has to the organization and the program.

Recognition and awards can be given in a variety of forms. The main factor for providing program impetus is ensuring that the recognition and awards are well publicized. Some of the most effective awards are pins, desk sets, pocket secretaries, etc. These token awards serve as constant reminders of program importance, engender good will toward the program, and publicize the program since most winners will prominently display their award. Other effective awards include certificates of merit for outstanding individual or group performance, and trophies and banners awarded on a group basis.

Recognition should be carried beyond the conferring of token awards. "Man of the Month" and "Man of the Year" programs can be implemented to honor the most significant individual contributors. These programs can be set up on company, division, department, and group levels simultaneously. Publicity can be arranged for significant error cause identification and ZD suggestion submitters on a timely basis. The formation of exclusive clubs (e.g. a "Craftsmanship Club" or "Crusaders Club") with membership criteria based on nomination for award or active participation can be highly effective as a form of recognition.

General

The key word is people—people with vastly different backgrounds, education, experience, interests, desires and preferences. These differences exemplify literally hundreds of dissimilar frames of references with which administrators of Zero Defects programs must work. Herein lies the exciting and dynamic challenge in providing continuity to a program that can only be as successful as the participants make it. The importance of the participants cannot be overemphasized!

Within the charter of a Zero Defects program, the administrator must have latitude to use any and all communication media available. This includes, but is not restricted to, company newspapers, magazines, telephone books, public address systems, management communiques, staff meetings at all levels, bulletin boards, employee information centers, posters, personal letters, and films.

By actual survey, there are thousands of companies and government agencies, defense oriented and otherwise, which have accepted the goal of no errors in their operations. These companies and agencies range from textile firms and manufacturers of drugs to food processors, missile producers, and school administrators. Each offers a broad and complex cross section of potential program participants with whom the ZD program administrators must work. These are participants because after the initial introduction, comes the real task of sustaining the highest interest possible by most of the employees within the confines and framework of the organization. Such interest results in less scrap, fewer errors, improved relationships, and on-schedule high-quality production. Obtaining these end results takes thoughtful action. The sustaining effort should encompass each employee at one time or another and as often as possible.

There are many methods that reap tangible and intangible benefits for employees, organization, division, company, and community. But there is no method that guarantees ultimate success in sustaining a program. Each program relies, necessarily, on the active participation of individual employees—employees who are, in fact, different from one another.

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INNOVATION AND RESEARCH

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Design, fabrication, and maintenance of products are not static functions. Necessarily, they must be adapted to changing needs; so continuing research must develop new products and improve current ones. It follows, therefore, that management must also recognize the need for change in quality control programs and techniques to keep pace with the evolving new products and manufacturing technology. Innovation in quality control is *sine qua non* and research in new quality practices and techniques take a critical role in the continuing effort to develop and produce products that truly satisfy consumer requirements.

The purpose of this paper is to outline areas where innovation and research are needed as elements of an overall industrial effort to produce better quality products. Areas of quality control are also identified because their challenging and dynamic nature are subject to more frequent and significant change. These areas may be classified under the headings:

- Vendor appraisal, selection and surveys
- Consumer research
- Specification preparation
- Process (or manufacturing) control techniques
- Quality costs
- Quality information program
- Economic ownership
- Motivation
- Personnel qualifications and training in quality control
- Safety

Vendor Appraisal, Selection, and Surveys

Vendor selection and quality control evaluation surveys are assuming increasing importance. With emphasis on competition, specialization, and the increasing dependence on vendor and subvendor sources, the problem of selecting optimum vendor sources represents a real challenge.

Source inspection, a practice long used to ensure effective control of vendor quality, places such heavy commitment on manpower that it is no longer a satisfactory technique. It is rapidly giving way to systems for surveying vendor quality capabilities and other techniques for continuously appraising vendor quality control programs.^{1, 2*}

These efforts are intended to ensure acceptable vendor-furnished parts and material. However, there appears to be a proliferation of different systems and procedures, and, further, increasing numbers of recurring surveys are falling on a large number of individual vendor organizations.³ Special-process vendors appear to be carrying the brunt of this impact.

Duplicative and nonstandard survey requirements inevitably result in higher costs, and there is ample justification for some form of standard procedure. Many individual companies, groups and industrial organizations, including the American Society for Quality Control, have undertaken programs to develop standard criteria for use in performing vendor surveys. However, as one might expect, these efforts have met with varying degrees of success, and the adoption of a single standard by all consumer organizations will likely not be immediate. Perhaps increased pressure and interest by industry groups, and the impact of less than totally effective surveys and evaluation programs on cost may ultimately bring about a common set of program requirements. These would encompass all essential elements of quality control program operation such as procedures, records, gage control and special processes control. In any event, many rather difficult problems need to be overcome.

One study of vendor surveys⁴ revealed what has been reported by a number of investigators as perhaps the most perplexing problem, that is the inability to evaluate effectively or relate the vendor's actual product quality to his survey rating. As a result, too many surveys have shown no appreciable difference in the quality of material from acceptable versus unacceptable systems.

* See reference list at end of paper.

Unfortunately, a universal survey procedure does not provide the ultimate answer. Of necessity, surveys should be flexible in terms of appropriately recognizing the different sizes and product categories of vendors. Failure to recognize some of the specialized or unique (to various product lines) program elements may impose dissimilar or inequitable requirements, especially on specialty suppliers. Surveys which adequately measure overall vendor capability, and which take into account smaller vendors and their relatively unsophisticated quality control systems, will lead not only to improved cost relationships but also to a broader selection of quality sources of supply and quality know-how.

Various qualitative schemes have been proposed and used to measure the overall quality performance of vendors. Because of their classically subjective character, most have been less than satisfactory. The subjectivity became coupled with problems inherent to integrating the many factors that must be considered in attempting to express numerically the quality position of any given supplier. Continuing effort to measure various elements of the overall quality program may, however, lead to an improved program for vendor evaluation that will include all important quality factors, thereby improving the objectivity of the vendor quality rating system.

Consideration has also been given to some means for pooling vendor evaluations as a means for eliminating overlapping evaluations.⁵ The establishment of such a system would not only enable consumers to save money, but it would eliminate the constant invasion on those suppliers who furnish products or processing services to many customers. While the rudiments of such sharing of "approved supplier" lists, including the availability of appropriate backup data, have been considered by a number of firms, we are still a long way from a universal system that can be readily used by all. The potential convenience, and savings in time and money, strongly suggests that this is an extremely fertile area for additional investigation.

A final item relating to the topic of vendor selection and surveys is the audit and its increased use and role in consumer-vendor relationships.

Audits have been used rather extensively over the years to perform internal (i. e., in-plant) checks on process or operation controls and on the performance of production, inspection, and operating personnel in general. They are used also to identify and isolate defect-causing conditions.⁶ More recently, audits have become popular for checking the quality of product; the extent of compliance with contracts for new and overhauled material; and for assessing the status of material during transport, storage, and return to inventory. Government agencies, in particular, because of the quantity, value, and sometimes criticality of an item, have been making increased use of audits. It is likely that the design and use of audits may well require increased quality control management attention in the future.

Surveys and audits seem to be reasonably effective techniques for evaluating the quality and control of select products and for obtaining corrective action, when such is necessary. Still unsettled, however, are the details and best procedure for performing the surveys and audits. Since these are not static functions, they should be re-examined continually to ensure that they are providing the expected results.

Consumer Research

By definition, consumer research ascertains and measures consumer requirements. In the Department of Defense, for example, it takes on the form of on-site surveys of product effectiveness and data feedback programs by which users make known their opinions of the effectiveness of products. The consumer (nondefense) markets, on the other hand, use extensive programs devised by advertising and other service agencies for measuring consumer needs. Usually, however, these programs do not return data that give clear visibility to the consumer's requirements and opinions on product quality. Information is extensive from market research studies on the buying habits of the public and their need for new products, but little is known about the public complaints of the quality of these products. Product quality and reliability are, however, becoming more important in consumer and other marketing research studies; although the pace is still slow, management is becoming more keenly aware of the necessity to consider customer needs and desires for quality.

Field service testing is another technique for evaluating potential consumer quality requirements. Products are used or operated in actual environments and assessed in terms of quality satisfaction of typical customers. Management has come to recognize that practicing the "caveat emptor" philosophy is no longer good business. Many firms are, instead, adopting the philosophy, "the customer is always right." Some have found that pretesting by actual customers offers market information which ensures sales growth. Manufacturers are thus better able to assess the true value customers place on the quality control dollars spent in producing a given item.

Performance and satisfaction of the product to the customer is probably the best single measure of effectiveness of a quality assurance program. If customers receive less performance than they think they should, the supplier of the product may be in deep trouble. Field service testing, therefore, is not only essential to effective quality control, it also could be an important adjunct to consumer research and marketability studies. The results of the tests are essential to the quality operation and cannot be disregarded or casually treated. The tendency, especially in small firms, to overlook the importance and usefulness of this barometer of quality performance has no doubt been responsible for the disappearance over the years of many products (and firms) from the market.

Price, quality, and availability of an item are considered key factors in maintaining a competitive market position. A declining economy often places unusual pressures on a company to maintain its quality position. Under such conditions, when profit-making is difficult enough without the added concern of trying to improve quality, it may be difficult, if not impossible, to keep price, quality, and availability in proper balance.

Under more prosperous economic conditions, on the other hand, this pattern shifts greatly. As the consumer enjoys greater purchasing capacity, quality in both design and conformance weigh more heavily in his choice. Profits and growth will come to those companies that furnish products in demand, and to those that are better able to measure or test, through consumer research and consumer studies, consumer desires as to price, quality, and design.

Specification Preparation

Basic to the communication of quality control requirements is the specification. It is critical in consumer-vendor relationships because it is the only instrument that describes exactly what the buyer wants. But accurate specification preparation is difficult, at best, and there is a paucity of literature on the technology of specification preparation to support this contention.

No other single facet of manufacturing presents the same continuing and perplexing problem of communicating clear and meaningful requirements effectively as the specification of quality control. This is a fact, whether the documentation is the formal published specification (e. g., military, federal, or industry group specifications) or the less formal descriptions that may be incorporated in the purchase order.

Fundamentally, the two foremost requirements of a product specification are the stated technical requirements of the item and a clear delineation of the examinations, inspections, and tests that are to be performed to ensure that all requirements are adequately met. Quality requirements must match the technical requirements, i. e., the inspections required must demonstrate clearly that each technical requirement is considered. The specification fulfills its quality control purpose when it communicates clearly and fully to the quality control people what they must do to ensure that the product conforms to requirements and that it will satisfy the purpose intended. If the specification fails to include everything needed to describe fully either the product requirements or the inspections and tests necessary to ensure compliance, neither the supplier nor the consumer can be assured that his interests or requirements have been satisfied.

In competitive contracting, adequate specifications and work statements are mandatory. Competition implies and requires a complete and understandable delineation of the contract or purchase agreement. Only when the description, specification, or engineering data clearly defines the product requirements, including quality and quantity requirements, does the basic criteria for competitive procurement exist. While competition is no assurance of quality, its absence is generally noted by higher prices. The lack of competition may also close the door to new ideas.

More often than we may care to admit, specifications and drawings contain insufficient data for suppliers to determine fully whether their products fulfill the customer's requirements. Both supplier and buyer are unable to even determine the proper inspection standards. Also, inadequate or incomplete specifications may make it necessary to consider the use of incentive contracts as a stimulus to encourage suppliers to undertake the work. In such instances, the obvious handicap resulting from the lack of good specifications then is that contracts cannot be accurately priced or administered.

The current concept that specification preparation (content and format) is the best way to communicate product requirements is now being questioned and studied. The concern is not for the specifying of technical design and quality control requirements for the simpler and well established items, but for the more complex items. The possibility is being explored of a new, more effective concept of specification preparation more suited to the problems inherent to time compression, high reliability, and high complexity in item development and production. The chief beneficiaries of the new method would be the engineers, specification writers, buyers, quality control people, and others who daily encounter this problem. Certainly, such new factors as very high reliability, quality costs, time-compressed research and development, and ultimate or life costs for maintaining an item over an extended life cycle are tremendous challenges to the conventional specification process.

Process or Manufacturing Control Techniques

Emerging new production processes and techniques have a profound impact on existing quality control and inspection practices as well as on existing measurement technology.⁷ Some of these processes have been developed to reduce product defectiveness and to improve overall quality performance. However, techniques for quantitatively measuring quality have not advanced as rapidly. Frequently, the technology to measure effectively (in some meaningful sense) the actual quality contribution of a new process makes it impossible to compare in an absolute sense the magnitude of the improvement.

One example of new processing is computer-controlled machine techniques, which are becoming more firmly established in many heavy and light industries.⁸ Numerical control (NC) technology has already become firmly entrenched in the machine tool business, where punched tapes are used not only to check machine performance but to measure and test the product as well. These machines are not limited only to monitoring and controlling banks of production and test equipment. The memory and computer capacity of the more advanced computerized systems are being used to store and analyze quality control data, including the identification of trends and the detection of potential problems. While these new systems systematically and effectively control simultaneously a few hundred variables which influence the quality of the product, they have the potential for instantly alerting quality managers and engineers to unsatisfactory trends or shifts in quality, thereby permitting immediate corrective action.

The potential of these new control techniques and processes has yet to be fully realized. Manufacturing plants of the future may be entirely automated with computer control processes and automatic inspection equipment. Food and chemical process industries have already proved their value. But the growth and expansion of new processes will depend, to a great extent, on the ability, vision, and imagination of quality control people to adapt their techniques to these methods. The translation of new process development technology to production practicality, especially as it relates to the consumer-vendor relationships, will test the quality assurance engineer. The challenge will be to establish meaningful, if not always practical, quantitative quality and reliability performance levels to meet customer needs as the new processes find their way into the day-to-day industrial routine.

Quality Costs

Synonymous with effective management is the continued and increasing attention to the goals of lower production costs and improved quality.⁹ Organizations are or should be constantly seeking ways to not only effect economies in their manufacturing processes, but also to improve the quality of their products—thereby reducing direct and indirect quality costs.

In a general sense, quality costs embrace all costs which bear on quality and their study. More specifically, they refer to the methods for ascertaining, in a given environment, the costs to producers and consumers of deficiencies in quality.

Management readily accepts the contention that increasing emphasis on the technical (design) side of the company enhances its competitive position. However, management frequently fails to recognize the role product quality plays in being competitive. Perhaps this misunderstanding stems from the difficulty in assessing quality costs—direct as well as indirect.

Much may be found in the literature on the importance of the various cost factors that make up quality costs and on what should be included in quality cost data. The need to keep these costs at a minimum without sacrificing the acceptable quality level is obvious in a competitive environment. Not so obvious, however, is the way to measure the full impact of customer dissatisfaction resulting from a defective or inferior product. Certainly it is inexcusable not to recognize the relationship of rework, scrap, and service costs to maintain an item versus costs of inspection and tests and the cost effectiveness of changes or correction to a process designed to reduce these losses by some measurable amount. Reasonably accurate estimates can be made of tangible defect losses, the cost of personnel and equipment to determine and eliminate the cause of such losses, the cost of new or modified equipment, and the cost of training personnel in the use of new processes. Once these costs have been determined, tradeoffs can be made accordingly. But all expenses incident to defects occurring often are not readily ascertainable.

The problem of establishing the optimum ratio of quality costs to prevention must take into account the quality desired by the consumer and the cost of consumer dissatisfaction. As a result, we are confronted with a problem whose solution does not lend itself to simple, straightforward mathematical treatment. The demands on business and the marketable value of each product is subject to constant change. A continuing study of new and more powerful techniques is needed to provide quality managers with a more accurate and valid basis for economic decisions. Quality management which continually strives to upgrade itself with new techniques for quality costing and quality cost reduction

that improves the accuracy of its financial management should expect a handsome return on the investment while simultaneously enhancing the value and reputation of the quality function.

Quality Information Program

Quality information programs include procedures which enable the producer to keep score on the quality performance of vendor-furnished supplies (for vendor rating). It also includes all internal (in-plant) data and information flow which describe the quality program operation and its results along with information generated by customer and field service activities. However, a discussion on innovation and research needs relating to total quality information would be boundless. Therefore, the comments in this paper are limited to deficiency data and deficiency data flow.

Fast and accurate reporting and analysis of deficiency data are essential to quality control. However, quality information is subject to excessive delays even though new and speedier devices have been developed to help accelerate the flow of information—e.g., transceiver networks, direct-line telephone and telegraph, and on-line computer service—and devices to speed up processing, e.g., high-speed computers with random access capability. Thus, quality trend information leading to the correction of faulty processes and operations arrives expensively late. Programs designed to produce real-time, continuous results are, relatively, still in their infancy.

Fast-reacting data systems should not generate data for data's sake, although many of the computerized efforts leave this impression. Reports from these systems should give quality control people and plant production people timely, concise, easy-to-understand information. Information generated from the program should be limited to the significant vital few problems and reported in such a way that production people can take immediate corrective action, and know, based on the data, precisely what action is required.

Fast-reacting, real-time systems impose a number of requirements on the inspection system, not the least of which is a simple, standard inspection report form containing standard elements of reported data.

Aside from the standard items of data, write-in information must be kept to a minimum.

Use of the computer does, however, have a number of rewards, i. e., the flexibility to provide a wide variety of reports collated by department, product, operation, shift, etc.

Automation or not, the problem of compatibility between in-plant deficiency data with field service and customer complaint data continues to plague many industrial and government quality control organizations. The merging of these two sources of quality information into a single, mass quality data analysis program—thereby measuring overall quality performance completely and accurately—should be possible, although quite difficult. Generally, field information lags behind in-plant data by as much as eight weeks. Hence, the difficulty in combining both data to portray the overall quality of production.

Since field and in-plant information usually represent two different reporting systems (and two different kinds of reports), the reconstructed corrective data are incompatible. (The in-plant data is usually more technically suited to failure analysis, whereas field service data and customer complaints are quite often of a more generalized nature.) While many investigators are trying desperately to improve the methods for reporting, reducing, and analyzing deficiency data, this problem will likely continue for a long time. New technology and equipment which will provide real-time field failure reporting may ultimately provide some relief, but in the meantime, it appears that the present deficiency data feedback procedures will prevail.

Economic Ownership

In more recent years, interest has increased in cost-of-ownership as the basis for selecting suppliers. First cost, i. e., the initial cost of a product, is being considered less as the sale basis for selecting sources of manufacture or supply. Instead, the concept of cost-of-ownership, which also is called ultimate cost, real cost, and total cost, has been gaining acceptance. Total cost considers, in addition to the initial cost, the cost of maintaining the item during the period considered to be its normal useful life. Unless this overall cost is adequately considered in

making a buy, purchases based on the lowest quoted price are frequently beset by costs incurred incident to supporting or maintaining the item once it is placed in the hands of the customer. These later costs often far outweigh the initial savings of the low bid.

Economic ownership pertains then to possibilities for developing new concepts for making ownership of products less costly through quality improvements. Ideas for exploring this subject may be found in the Department of Defense Directive 4100.35, Development of Integrated Logistic Support for Systems and Equipment, dated January 19, 1964. Through this directive, the cost of developing the integrated logistics support (which includes provisions for planned maintenance of the equipment) must be recognized as an inherent item in the overall costs for delivery of an operationally effective system or equipment.

Although this concept is not new, and while some work has progressed on ultimate- or real-cost applications to procurement, little practical experience exists. Development of a procurement-program making use of this concept will not be easy because in only a very few cases is total cost information available, or, when it is, the data usually applies to items that were acquired from more than one source. Under these conditions, it is difficult if not impossible to pinpoint the maintenance cost attributed to specific manufacturers.

In the past 10 years, warranty and guaranty provisions have been widely instituted as an incentive to reduce overall equipment costs, especially those associated with marginal quality and reliability of the product. Somewhat allied to warranties is the growing interest of consumers in buying from suppliers with field service organizations. While these practices constitute a hedge against ownership costs resulting from equipment failures and defects, it is most appropriate their use be recognized as beneficial when the maintenance and logistics costs of supporting an item through its useful life cannot be readily ascertained by the user.

Motivation

Many defects are daily reminders that not all of our quality problems can be solved by adjusting the process, replacing equipment, increased training, or following any of the other conventional quality practices prescribed for defect prevention or elimination. Contrary to arguments frequently advanced, many of today's quality problems are not due to technological changes in the product. Rather, many defects indicate that their cause too often is an absence of reasonable attention to quality and inspection requirements.

Poor workmanship, inattention to detail, and, in general, the absence of a pride in quality workmanship is an attitude problem that can be solved only by techniques oriented to change worker attitudes.

A partial, if not a total solution to this problem is the Zero Defects type of motivational program. These programs, which challenge people at all levels to become more quality conscious and stress the need for error-free performance, strike at the heart of the attitude problem. Workmanship errors and defects are normally attributed to either lack of knowledge of the job or inattention to details. Assuming, of course, that the worker has the capability of doing the job, only training can correct the first condition. Zero Defects programs will, if properly designed, installed, and operated, contribute to the substantial reduction in workmanship errors by instilling a pride in performance, and a dedication on the part of workers to "do the job right the first time."

Concern has been raised over whether having run their initial course, these programs will disappear like other motivational programs. Results to date indicate that if properly developed, implemented, and managed, and with periodic reviews to identify new and fresh ideas that can be used to keep the program moving forward, the ZD programs will have a long future. The challenge of continued program success, then, seems to lie in the ability to give the program an occasional nudge with new and unusual ideas that keep worker interest in the objective of error-free work at a reasonably high pitch.

Personnel Qualifications and Training in Quality Control

Whether quality control continues to advance in its professional stature will depend, in large part, on the ability of quality control personnel to meet the challenge of effective program management. They will have to keep continually abreast of and make use of new inspection and quality control methods, technology, and management practices. The growth in importance of the quality function since World War II can be measured by the fact that quality control directors and managers are part of top management, and, in a few cases, are at corporate level positions.

Technological advancement demands the continual upgrading of the entire quality control force—from competent line inspectors up through top management. In addition, the very nature of quality control work has been increasing in its technical and engineering character. Scientific techniques such as statistical methods, advancements in processes and production technology, need for greater depth of technical knowledge of the product (i.e., how it works and the effects of defectiveness on ultimate performance), are just a few of the factors that have helped shift quality control from an art to a science.

Part of the upgrading of competence involves quality control training; virtually an unlimited choice of location and subject matter are available, and universities, technical and management national societies, consultants, many companies, and government agencies all seem to have become preoccupied with the business of training quality control specialists in one or more subjects. In fact, the opportunity for instruction is so great that it leads one to ask "Just how effective are many of these short course programs?"

At the university level, formalized degree programs for quality control and quality control engineering education are still rare. Although the need exists, progress will be slow until students can be attracted to these programs, and universities find it profitable to structure and offer special degree and associate degree programs in quality control.¹⁰

A recent Department of Defense study, in which quality control and quality control management problems were examined comprehensively, agrees generally with the points cited above.¹¹ The splintered or disjointed role of quality control work, lack of specific and unique (to quality control) skill identification, and the need for a more positive and elaborate career development program with careful expansion of academic curricula to cover the quality control function were quite evident from this study.

Perhaps a small part of the problem has been one of nomenclature (if not of pure semantics), which has worked against quality control. Top management has had some difficulty keeping up with the changing titles, functions, responsibilities, and personnel as quality control has emerged as a profession. Quality organizations have progressed from the original old-line inspection function, through titles such as quality control, quality assurance, product assurance, and reliability and quality assurance. Perhaps not the least confused (and certainly not in complete agreement) have been the quality control program managers themselves. Moreover, the splintering and establishment of what has been viewed in some circles as the new disciplinary areas (e.g., Zero Defects, Value Engineering, Reliability, Nondestructive Inspection) has not enhanced the emergence of a strong, virile quality control organization. The proliferation of skills and the lack of agreement and standards in many of these associated skill areas further contributes to this problem.

Hopefully, the leadership of the Department of Defense study in trying to tackle the problem of skills acquisition, development and retention, including identification of a training program, may ultimately lead to a clearer functional role for quality control within the defense establishment. Hopefully, too, it should serve as a stimulus in both industry and academic circles to direct greater effort toward the resolution of this problem as it affects the profession and the nation generally. Certainly, quality control managers have a responsibility for putting their own profession on a firmer basis by eliminating some of the needless confusion associated with the terminology. It is time for greater unity to reflect itself in the development of a universal language (via, standard nomenclature) and operating codes that will facilitate the task of defining skills, functions, and curricula.

Safety

Safety and product liability are playing an increasingly important role in the development and use of consumer products. Not only is this role concerned with safety features designed into a product, but also with the ultimate use of the product by the consumer. Recent Congressional hearings on automotive safety standards highlights what can happen in a major segment of our industry when unsafe or hazardous conditions are detected relative to the use of the products involved.

The new National Traffic-Motor Vehicle Safety Act (1966) sets demanding standards for motor vehicle equipment and tires. This legislation will have far reaching effects on inspection and quality control in the automotive and allied industries. Besides tighter standards, increased inspections, and more stringent quality requirements, generally, an important quality feature of this act is that it goes beyond production by requiring manufacturers to notify all purchasers and dealers of any defect found after delivery or during the service life of the vehicle.

In 1965, product liability cases numbered 50,000.¹² Publicity had no doubt helped swell this number. This is not to say, however, that some of the cases are not just and valid. The increased number of claims emphasizes the need to more fully consider how suitable design, inspection, and use instruction can improve safety and reduce personnel hazards in consumer items.

Field service information can be especially useful in pointing up unsafe conditions concerning product use. Troubleshooting by a team of engineering, quality control, and production people can lead to the early detection of hazardous conditions and the correction of potential problems before they result in serious claim actions. Where a defective production item suggests a hazard or safety problem, recall of other items for examination and correction also contributes to keeping in check failures or defects that may lead to more serious financial liability. And finally, published information for dealers and direct distribution to customers can often pay real dividends in customer satisfaction as well as prevent a serious accident.

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APPENDIX A

SUGGESTED MEASUREMENT CHARACTERISTICS FOR VARIOUS FUNCTIONAL GROUPS

The following lists provide examples of what to measure in various functional groups.

1. ACCOUNTING

Percentage of significant errors in reports: total number of reports

Percentage of late reports: total number of reports. Average reduction in time spans associated with important reports.

Pinpointing high-cost manufacturing elements for correction

Pinpointing jobs yielding low or no profit for correction

Providing various departments with the specific cost tools they need to manage their operations for lowest cost

2. ADMINISTRATIVE

Success in maximizing discount opportunities through consolidated ordering

Success in eliminating security violations

Success in effecting pricing actions so as to preclude subsequent upward revisions

Success in estimating inventory requirements

Success in responses to customer inquiries so as to maximize customer satisfaction

3. CLERICAL

Accurate typing, spelling, hyphenating

Decimal points correctly placed

Correct calculations in bills, purchase orders, journal entries, payrolls, bills of lading, etc.

Time spent in locating filed material

Percentage of correct punches

Paper used during a given period versus actual output in finished pages

4. DATA PROCESSING

- Promptness in output delivery
- Effectiveness of scheduling
- Keypunch errors
- Depth of investigation of programmers
- Computer downtime
- Program debugging time
- Rerun time
- KP efficiency

5. ENGINEERING: DESIGN

- Adequacy of systems specifications
- Accuracy of system block diagrams
- Thoroughness of system concepts
- Simulation results compared to original design or prediction
- Success in creating engineering designs that do not require change in order to make them perform as intended
- Success in developing engineering cost estimates versus actual accruals
- Success in meeting self-imposed schedules
- Success in reducing drafting errors
- Success in maximizing capture rates on RFP's for which the company was a contender
- Success in meeting engineering test objectives
- Number of error-free designs
- Correct readings of gages and test devices
- Accurate specifications and standards
- Proper reporting and control of time schedules
- Reduction of engineering design changes
- Changes in texts or in illustrations of reports
- Rework resulting from errors in computer program input
- Advance material list accuracy
- Design compliance to specifications
- Customer acceptance of proposals
- Meeting schedules
- Thoroughness of systems concepts

5. ENGINEERING: DESIGN (Continued)

Accuracy and thoroughness of reports
Adequacy of design reviews
Compliance to specifications
Adequacy of design reviews
Accuracy of computations
Accuracy of drawings
Reduction in number of ECN's to correct errors

6. ENGINEERING: MANUFACTURING

Accuracy of manufacturing processes
Timely delivery of manufacturing processes to the shop
Accuracy of time study data
Accuracy of cost estimates
Timely response to bid requests
Asset utilization
Accuracy and thoroughness of test processes
Adequacy and promptness of program facilitation
Application of work simplification criteria
Minimum tool and fixture authorization
Labor utilization index
Methods improvement (in hours or dollars)
Contract cost
Lost business due to price

7. ENGINEERING: PLANT

Effectiveness of preventive maintenance program
Accuracy of estimates (dollars and details)
Accuracy of layouts
Cost of building services
Completeness of plant engineering drawings
Adequacy of scheduling
Fixed versus variable portions of overhead
Maintenance cost versus floor space, manpower, etc.
Lost time due to equipment failures
Janitorial service

7. ENGINEERING: PLANT (Continued)

- Success in meeting or beating budgets
- Instrument calibration error
- Fire equipment found defective
- Lost time due to equipment failures
- Purchase requisition errors
- Schedule compliance
- Timely response to bid requests
- Adherence to contract specifications
- Effectiveness of provisioning parts breakdown
- Timely preparation of priced spare parts lists
- Effectiveness of customer liaison
- Effectiveness of cost negotiations
- Status "ship not bill"

8. FINANCE

- Billing errors
- Vouchers prepared with no defects
- Clock card or payroll transcription errors
- Keypunch errors
- Computer downtime
- Timeliness of financial reports
- Effectiveness of scheduling
- Program "debugging" time
- Rerun time
- Accuracy of predicted budgets
- Clerical errors on entries
- Inventory objectives met
- Payroll errors
- Discounts missed
- Amounts payable record

9. FORECASTING

- Can departments function with maximum effectiveness with budgets set for them?
- Can the company buy needed capital equipment, keep inventories supplied, pay its bills?

9. FORECASTING (Continued)

Do projects meet time schedules ?

Assistance to line organizations (Scheduling, Planning, and Control Functions)

Methods for finance and cost control

Timeliness of financial reports

Assets control

Minimizing capital expenditures

Realistic budgets

Clear and concise operating policies

Timely submission of realistic cost proposals

Completeness of financial reports

Effectiveness of disposition of government property

Effectiveness of cost negotiations

10. LEGAL

Amount of paper used versus finished pages produced

Misdelivered mail

Misfiled documents

Delays in execution of documents

Teletype errors

Patent claims omitted

Response time on request for legal opinion

11. MANAGEMENT

Management can be gaged by the output of staff elements, overall defects rates, budgets and schedule controls, and other factors that reflect on managerial effectiveness. In other words, the accomplishments of a manager are the sum totals of those working under him.

Success in meeting or beating budget

Success in developing estimates of costs versus actual accruals

Success in meeting schedules

Performance record of employees under his supervision

Success in developing realistic estimates on a PERT or PERT/ Cost chart

Success in minimizing use of overtime operations

11. MANAGEMENT (Continued)

All nonproduction departments can be measured.

Each department should be measured against itself, using time comparisons, and preferably by itself.

The best primary goals are those that measure cost performance, delivery performance, and quality performance of the department. Secondary goals can be derived from these primary goals.

There should be a base against which quality, cost or delivery performance can be measured as a percentage improvement. Examples of such a base would be direct labor, the sales dollar, the material dollars, or the budget dollar. A dollar base is more meaningful to Management than a physical quantity of output.

Success in effecting pricing actions so as to preclude subsequent revisions

Pages of data compiled with no defects

Clarity and conciseness of operating procedures

Evaluations of capital investment

Errors in applying standards on process sheets

Accuracy of estimates: actual costs versus estimated costs

Effectiveness of work measurement programs

12. MARKETING

Success in reduction of defects through suggestion submittal

Success in capturing new business versus quotations

Responsiveness to customer inquiries

Accuracy of marketing forecasts

Response from news releases and advertisements

Effectiveness of cost and price negotiations

Success in response to customer inquiries (customer identification)

Customer liaison

Effectiveness of market intelligence

Attainment of new order targets

Operation within budgets

Effectiveness of proposals

Exercise of selectivity

Control of cost of sales

Meeting proposal submittal dates

12. MARKETING (Continued)

- Timely preparation of priced spare parts lists**
- Customer liaison**
- Aggressiveness**
- Effectiveness of G-2**
- Utilization of field marketing services**
- Dissemination of customer information**
- Bookings budget met**
- Accuracy of predictions, planning, and selections**
- Accurate and well-managed contracts**
- Exploitation of business potential**
- Effectiveness of proposals**
- Control of printing costs**
- Application of standard proposal material**
- Meeting proposal submission dates**
- Standardization of proposals**
- Reduction of reproduction expense**

13. MATERIEL

- Saving made**
- Late deliveries**
- Purchase order (PO) errors**
- Material received against no PO**
- Status of unplaced requisitions**
- Orders open to government agency for approval**
- Delays in processing material received**
- Damage or loss items received**
- Claims for products damaged after shipment from our plant**
- Delays in outbound shipments**
- Complaints or improper packing in our shipments**
- Errors in travel arrangements**
- Accuracy of route and rate information on shipments**
- Success in meeting schedules, material shortages in production**
- Success in estimating inventory requirements**
- Clock card errors by employees**
- Damaged shipments**

13. MATERIEL (Continued)

Stock shelf life exceeded
Items in surplus
Purchase requisition errors
Effectiveness of material order followup
Adequacy and effectiveness of planning and scheduling
Application of residual inventories to current needs
Inventory turnover
Manufacturing jobs without schedules
Timeliness of incorporating ECN's
Timely replacement of rejected parts
Adequacy of reject control plan
Effectiveness of packing operation
Application of residual inventories to current needs
Floor shortages
Labor utilization index
Data Processing rerun time on material programs
Bad requisitions
Value of termination stores and residual inventory
Manpower fluctuations around mean
Percent supplier material (\$) rejected and returned:
total material \$ purchased
Number of defective vendors (repetitive): total number
of vendors
Number of single source vendors: total number of vendors
Percent of supplier material (\$) holding up production:
total material \$
Number of late lots received (actually holding up production):
total lots received
Percent of purchased material (actual): total material bid
or budgeted
Percent of reductions in B/M effected through purchasing
effort: total material bid or budgeted
Correct quotations or rates

13. MATERIEL (Continued)

Customers call back as promised
Installation of exact equipment requested by customer
Appointments kept at the time promised customers
Prompt handling of complaints
Accurate meter readings
Courteous treatment of customers
Right packages of goods ordered shipped
Number of telephone numbers correctly dialed
PMI rejects
Savings made
Material handling budget met
Travel Expense against open shop orders
Orders to government for approval—disapproved, resubmitted,
and open, not approved

14. PERSONNEL

Success in eliminating security violations
Hiring effectiveness
Thoroughness and speed of responding to suggestions
Employee participation in company sponsored activities
Administration of insurance programs
Accident prevention record
Processing insurance claims
Provision of adequate food services
Personnel security clearance errors
External classified visit authorization errors
Speedy processing of visitors through lobbies
Records accuracy
Adequacy of training programs
Thoroughness and speed of investigating suggestions
Employee participation in company sponsored activities
Grievances
Employment requisitions filled
Administration of insurance program
Acceptance of organization development recommendations

14. PERSONNEL (Continued)

Effectiveness of administration of merit increases
Overhead budget performance

15. PRODUCT ASSURANCE

Participation in design reviews
Customer liaison
Technical society participation
Accuracy of proposals and contracts
Application of program policies
Prevention of field complaints
Effectiveness of reporting and recording
Customer rejects
Rejected material on the floor
Adequacy of vendor ratings
Effectiveness of field quality control
Rejects
Screening efficiency
Inspection documentation
Quality Assurance audits

16. PRODUCT CONTROL

Success in developing realistic schedules
Success in developing realistic estimates
Success in identifying defective specifications
Process sheets written with no error
Transportation hours without damage to product
Parts shortages in production
Down time due to shortages

17. PRODUCTION

Success in reducing the scrap, rework, and "use-as-is"
categories
Success in maintaining perfect attendance records
Success in identifying defective manufacturing specifications
Success in meeting production schedules
Success in cost reduction through suggestion submittal

17. PRODUCTION (Continued)

- Success in improving First Article acceptance**
- Performance against standard**
- Success in reducing required MRB action**
- Utilities improperly left running at close of shift**
- Application of higher learning curves**
- Floor parts shortages**
- Delays due to rework, material shortage, etc.**
- Control of overtime (nonscheduled)**
- Prevention of damage to work in process**
- Cleanliness of assigned areas**
- Conformance to estimates**
- Suggestions submitted**
- Labor utilization index**
- Defects**
- Asset utilization**
- Scrap**
- Utilization of correct materials, drawings, and procedures**
- Prevention of damage**
- Safety records**
- Inches of weld with no defects**
- Log book entries with no defects**
- Security violations**
- Compliance to schedules**
- Accuracy of estimates**

18. PROGRAM MANAGEMENT

- Liaison with customer**
- Financial**
- Quality of proposals (technical approach, cost, time)**
- Soundness of project plans**
- Coordination of support activities**
- Satisfactory field selloff**
- Backlog**
- New business volume versus budgeted**

19. PUBLICATIONS

- Compliance to specifications
- Errors corrected
- Thoroughness of coverage
- Usefulness of material
- Quality of production

20. QUALITY CONTROL

- Inspection errors
- Sampling program errors
- Timeliness of inspection reports
- Adequacy of vendor quality ratings
- Returned goods and field rework due to inspection oversight; customer rejects
- Quality assurance audits
- Inspection documentation
- Customer liaison

21. RESEARCH AND DEVELOPMENT

- Can it be applied?
- Can it be developed?
- Can it be manufactured?
- Can it be marketed?

22. SECURITY

- Personnel security clearance errors
- Timely and accurate processing
- External classified visit authorization errors
- Accurate processing of visitor identification
- Effectiveness of security program
- Guards, security checks, badges, passes
- Records accuracy
- Fire watch

23. SERVICES: GENERAL

Promptness in reply to requests

Quality of service rendered

Blueprint and drawing control, reproduction, distribution

Test equipment maintenance and calibration

TRW communication

Reproduction facilities

24. SUPERVISION

A supervisor's performance is measured by the overall effectiveness of his department; in other words, he is judged by the sum total of accomplishments of the people working for him. The worth of individual or group achievements should be evaluated against the following criteria:

Impact of potential error (abort of mission, cost effect on schedules, etc.)

Contributions of the individual or group to the prevention of error

Difficulty of the job and level of skill required

Work schedules and load impact on error potential

Ability of individual to correct his own errors

Attitude of the individual toward work, project, or command mission